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GEOLOGICAL MAGAZINE

VOL. LXXXIX. No. 3. MAY–JUNE, 1952

Issued 2nd June, 1952.

Notes on the Structure of some Minor Outlying Occurrences of Littoral Trias in the Vale of Glamorgan.

By TREVOR M. THOMAS

ABSTRACT

Active or recently-active, large-scale quarrying operations within the Carboniferous Limestone Series of this area, and ranging in location from the near-junction areas to points about half a mile removed from the southern boundary of the main littoral Trias outcrops, have afforded excellent sections displaying remnants of a former Triassic cover. It is considered unlikely that the latter outliers, of limited dimensions, occur in areas further removed than about one-third of a mile south of the existing limits of the main Triassic outcrops.

INTRODUCTION

THE Triassic rocks of Glamorgan include representatives of the Keuper subdivision and rest with major unconformity upon a deeply-denuded surface composed of strata ranging in age from Silurian, east of Cardiff, to Pennant Grit, east of Llanharan. Over the central and western portions of the Vale of Glamorgan, however, the bulk of the Triassic wrappings, overlapping the older structures to the south of the Coalfield, have rocks of the Carboniferous Limestone Series as their basic foundation.

The littoral Trias of this area forms a basal or fringe zone to the Keuper Marl proper and has a maximum thickness of 100 to 120 feet. Despite this limited thickness, the removal of the original covering of Keuper Marl and Lower Lias by post-Mesozoic erosion has resulted in the formation of fairly extensive outcrops in the vicinities of Llanharry, St. Mary Hill, and Coychurch.

This littoral variation of the Keuper Marl consists of a series of limestone breccias or conglomerates, inorganic limestones, and sandstones with bands of calcareous marls. The cementing matrix of these shore-line deposits is normally a calcareous mud which might have been derived as a residual deposit from the attrition of the limestone of the immediate hinterland.

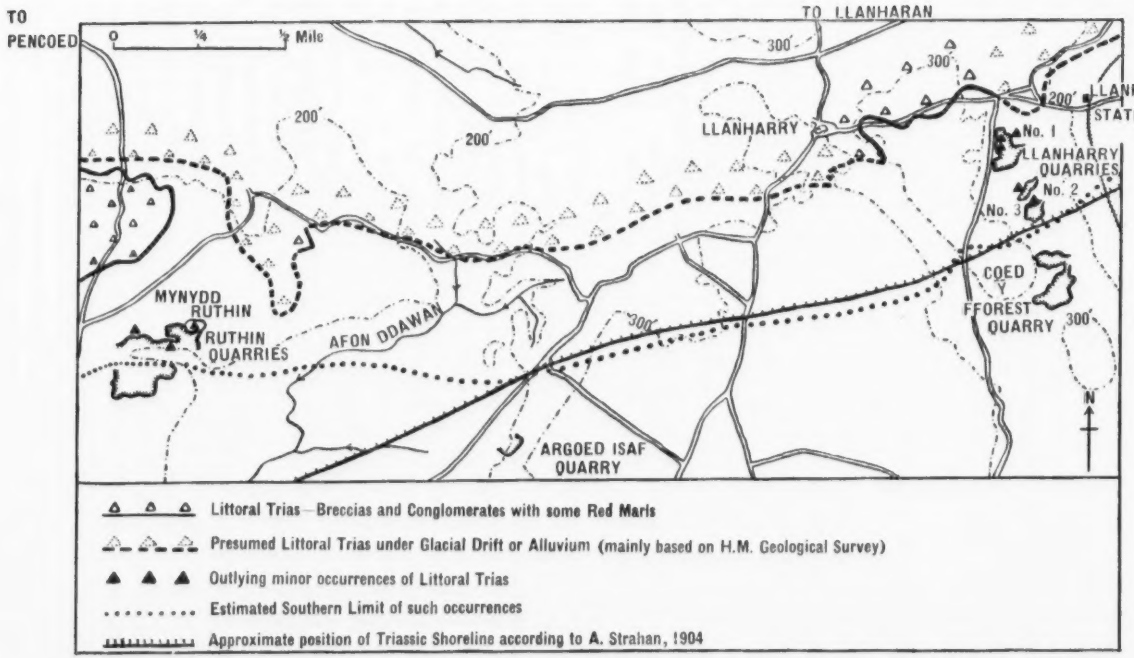
The Llanharry–St. Mary Hill Area

The area under review forms a stretch of undulating low-plateau country, approximately 3 miles in length, about half a mile in width, and with east-north-east to west-south-west alignment. Average elevations are in the order of 200 to 300 feet. A southward-flowing stream—the Dawen—has its source in the central sectors of the area, and its flat-bottomed floor contrasting sharply with comparatively steep valley sides, of limited height, forms the main topographical variation in an otherwise somewhat monotonous landscape.

The southern boundary of the main outcrop of littoral Trias runs west-south-westward through Llanharry village, and its minor sinuosities appear to be relics of shallow inlets or bays in the old Triassic shoreline. In the central sectors, coinciding with the upper Dawen valley, this boundary is concealed by drift, but to the north of Mynydd Ruthin in the west there is a major outlying capping of Trias, some three-quarters of a mile in length.

Extending southwards from the main Trias belt is an area of Carboniferous Limestone more than 3 miles in width. In the northern ½ mile, and immediately adjacent to the Triassic outcrop or cappings, the upper zones of the Main Limestone are represented. For the most part these consist of massive grey oolitic limestones, giving way southward to dark-blue, shelly or crinoidal limestones. To the south of Llanharry about 300 feet of thinly-bedded limestones with some minor shale partings separates these two predominant types. The Upper Limestone Shales are not represented in this vicinity, and the Main Limestones have a regular north-north-westerly dip, at angles of 15° to 25°, before giving way upward to the shales of the overlying Millstone Grit some distance north of the boundary of the Triassic overlap.

Natural rock exposures are of limited occurrence, but this is more than offset by the relative abundance of quarried sections. Active quarrying operations, now confined to the Carboniferous Limestone outcrop, are concentrated at three centres. In the east and to the south of Llanharry railway station, Coed y Fforest quarry and the Llanharry quarries, to the north which were closed in 1946, provide an excellent section with only minor interruptions and more than half a mile in length. This interrupted section is directed south-south-eastwards, across the Carboniferous Limestone and at right-angles to the southern boundary of the main Trias outcrop ; it is thus in the best possible position to determine the existence or otherwise of outlying remnants of a previous Triassic cover. In the central sector the active quarry of Argoed-isaf, on the eastern slopes of the Dawen valley, has a face more than 100 yards long and up to 150 feet in



TEXT-FIG. 1.—Map showing the southern edge of part of the Trias outcrop of the North Central Vale of Glamorgan.

height, but it is rather isolated and is about half a mile south of the conjectural boundary of the Trias beneath the drift or alluvium of the valley floor. Thirdly, in the west, on Mynydd Ruthin, the extensive Ruthin quarries have a working face more than 200 yards long. This, together with the older, northern, and abandoned part of the workings, affords a section, some 500 yards in length, which although directed at a very acute angle to the strike of the limestone is, at its furthest extension, one-third of a mile from the nearest point of a major Triassic outcrop.

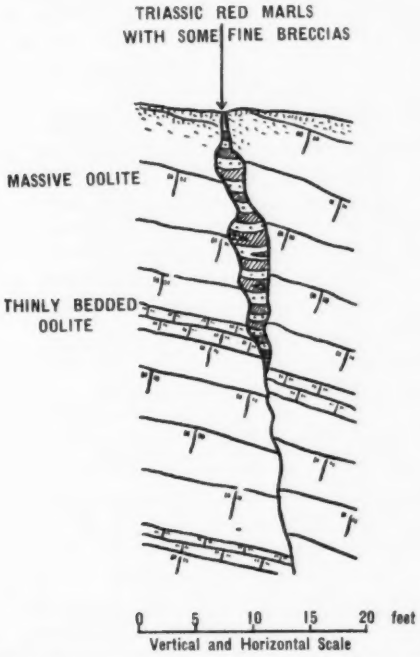
Outlying Occurrences of Littoral Trias within the Carboniferous Limestone

Minor outliers of littoral Trias, recorded to date, are confined to those features which form part of the rock sections in the recently-active quarries to the south of Llanharry railway station in the east, and Ruthin quarries in the west. Argoed-isaf quarry in the central sector shows blue-grey standard limestones traversed by three or four major joints or fractures, but these are either clean cuts or are filled with recent earthy or rubbly material. It is, however, highly probable that the Carboniferous Limestone immediately south of the main Trias outcrops has similar Triassic " inclusions " to those of Ruthin and Llanharry.

The recently-active quarries of Llanharry were worked as three distinct units. The northernmost and much the larger quarry worked massive light-grey oolitic limestones to a maximum depth of about 50 feet. Remnants of outlying Trias patches on the abandoned faces are not impressive. The north-central part of the eastern face was cut partly along a major joint. In this latter, red marly sandstones have been preserved down to depths of at least 20 feet from the surface. The sandstones are comparatively fine-grained and a fair proportion of their bulk appears to be made up of minute rhombs or irregular flakes of calcite giving some of the rock the appearance of a micaceous sandstone. The patch left has dimensions of 10 feet by 6 feet, and on available evidence the joint-filling had a maximum thickness of approximately 3 feet. Post-Triassic mineralization has modified these marly sandstones as they contain cavities, 12 inches to 18 inches across and lined with well-formed crystals of dog-tooth spar. The western face of the quarry has been terminated parallel and in close proximity to a series of major joints or minor dip-fault planes. These planes have been coated with stalagmitic material, but at two points minor wedges of marly sandstones, up to 2 feet thick and as much as 40 feet below the original surface of the ground, are to be observed.

The second quarry lies 100 yards to the south-east. It is on a much smaller scale than the first, but has worked similar light-grey oolitic

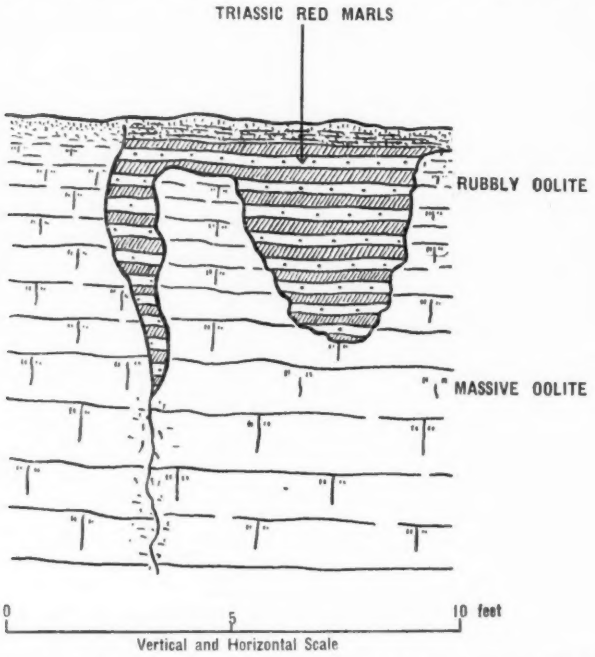
limestone to a depth of about 40 feet. The northern face shows two main beds of massive limestones separated or terminated by bands, 2 to 3 feet thick, of thinly-bedded stone. These are cut by a near-vertical fault with downthrow to the east of 3 feet. This fault fissure has been filled to a depth of 20 feet and with a maximum thickness of 3 feet by a wedge of Triassic sediments. The latter are red marly sandstones



TEXT-FIG. 2.—Diagrammatic section in Llanharry Quarry, No. 2, showing fault fissure in Carboniferous Limestone filled with Triassic sediments.

which include irregular minor intercalations of fine breccias with acutely-angled limestone fragments up to 2 inches long. In the upper limits the fissure is restricted to a width of about 6 inches, but this swells to 3 feet before tapering off and giving way in depth to a thin calcite vein with traces of haematite or limonite. Within this wedge of Triassic sediments indistinct bedding-planes are to be observed, although these have lost their original horizontal disposition and have become slightly convex downwards. A few fragments of reptilian bones or teeth have been found.

Immediately to the south and separated from the second quarry by a narrow neck of unworked ground is the last quarry of the Llanharry group. Evidences of a former Triassic cover occur in the form of red staining along major joints on the southern face and more conspicuously as a composite filling on the northern face. This latter shows a large fissure and a solution hollow or pipe, in juxtaposition



TEXT-FIG. 3.—Diagrammatic section in Llanharry Quarry, No. 3, showing composite joint and solution hollow filling of Triassic sediments.

(Note. The major part of this section was removed immediately prior to the cessation of active quarrying.)

to each other, which have been filled to a depth of 5 to 6 feet with compact fine-grained red marly sandstones.

The active quarry of Coed y Fforest and its adjacent extinct predecessor are located about 200 yards to the south-south-east of the southernmost Llanharry quarry. A dip section more than 300 yards long is provided by these two excavations. A well-marked fault-plane, major pipes and irregular solution hollows within the limestone contain no Triassic sediments.

Rather less than 3 miles to the west-south-west are Ruthin quarries,

occupying the southern edge of the limited stretch of rough downland referred to as Mynydd Ruthin. The active quarry with its 200 yard face, cut to a maximum depth of about 70 to 80 feet, is being advanced southward at a fairly rapid rate. It is thus being directed away from the main Triassic outcrops one-third of a mile to the north-west. Grey oolite and shelly limestones are worked. Mineral veins along joints are nowhere conspicuous, and in an advancement of the face by more than 100 yards in the past decade no joint or cavity filling of Triassic material has been encountered. In contrast to this, three occurrences of littoral Trias can be observed on the northern and older part of these extensive workings.

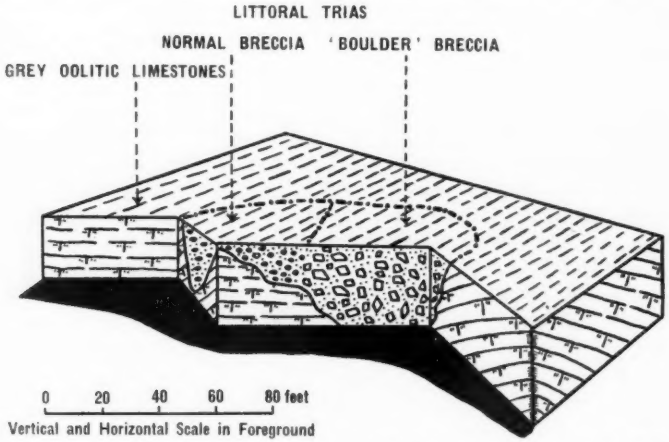
In the extreme north-east and to the north of the existing lime-kilns is a somewhat detached quarry with an abandoned face more than 120 yards long and up to 25 feet in height. The original intention was to extend this quarry further northward and working the grey oolites in its path. An unsuspected outlying patch of Trias, of comparatively large dimensions, brought this programme to an untimely end. The main feature of the eastern half of this abandoned face is thus a major cavity filled with highly variable Triassic accumulations. The slightly sinuous line of the face provides a longitudinal and transverse section of this cavity in continuity to each other. Estimates based on these put the maximum dimensions of the cavity as being : length 100 feet, width 40 feet, and depth 30–35 feet.

The variation of the littoral accumulations within this cavity is worthy of special comment. The eastern and larger half, as shown in the major part of the longitudinal section, is composed of large angular blocks of oolitic limestone, up to 8 feet in length and cemented together by a matrix of red marl and in-fillings of moderately-coarse red breccia. In the western half of the cavity there is an abrupt change, and the dominant Triassic filling material is a light-red breccia with angular fragments of limestone up to 4 inches in length.

The form of this feature and the nature of its filling materials are such as would suggest its origin as being due to the collapse of a cave within the Carboniferous Limestone on or near an inlet of the former Triassic shoreline. None of the component limestone blocks have a rounded face or coating of stalagmitic calcite as would support this theory, but for a distance of more than 100 yards to the west the Carboniferous Limestone shows a close series of major joints coated with stalagmite and forming a direct continuation of the long axis of the Trias-filled cavity. The abrupt change in its deposits from ultra-coarse in the east to those of normal littoral type in the west might be attributed to the excessively asymmetrical form of the long section of the former cave giving a gravitational concentration of the collapsed large blocks at the greater depths of its eastern sector.

One hundred yards to the south-west and at a lower level in an old rock face a portion of a large joint may be seen. This has been filled with a red sandy marl and has a maximum thickness of a few feet. As at Llanharry, where similar occurrences have been described, these marls give way with depth to irregular calcite veins with considerable traces of limonite or haematite.

The most important minor outlier of littoral Trias, determined to date, is located 200 yards to the west of the last feature and on an old

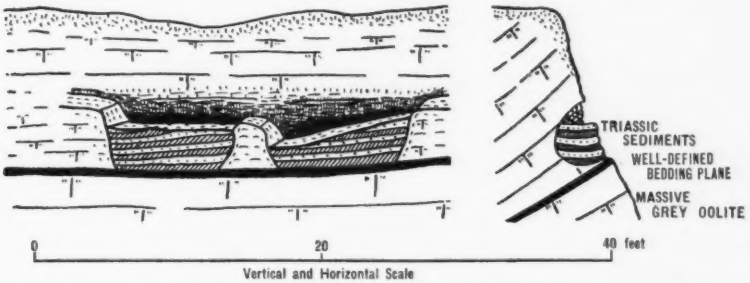


TEXT-FIG. 4.—Simplified block-diagram of old quarry face at Ruthin, showing the structure of an outlier of coarse Triassic material.

face immediately north of the offices of Ruthin quarries. The significance of this last outlier is not a corollary of its size or distinctive form but rather of the abundance of its included reptilian remains. The containing old face of limestone has been more or less cut as a strike section, 30 feet deep and in massive oolites. The top 10 feet of rock is inclined to be rubbly and this is sharply demarcated from the lower rock by a well-defined bedding plane in places occupied by a variable thin parting of shale or clay. Utilizing this bedding plane as a base-line is an accumulation of Triassic sediments which in long section is in the form of a pothole filling. The maximum length of this pothole is about 20 feet if one allows for a central ridge of limestone which splits it into two distinct chambers. The thickness of Triassic sediments remaining varies from 3 to 5 feet. Normally one would expect these sediments to extend to the top of the section or at least to give way upwards to newer or superficial deposits. This is not the case here as the patch of Trias is seemingly overlain

by a few feet of rubbly oolite. The upper line of contact of the two systems is a smooth surface sloping inwards into the main mass of enveloping limestone. The lithology of the sediments and the form of this contact point strongly to these former originating in an old cave, pre-Triassic in date and with a connection of limited dimension (possibly a joint plane) linking it to the overlapping Trias.

The deposits occupying the remnants of this old cave are all fine-grained, this latter characteristic necessitating the condition of a limited



TEXT-FIG. 5.—Strike and dip sections of top of old face at Ruthin quarries illustrating pothole-like occurrence of outlying Triassic deposits.

upper access and thus acting as a filter to coarser-grained or pebbly material. Buff-brown, light-textured, and fragile paper shales ; red, marly, and somewhat flaggy sandstones ; and yellow-grey, inorganic limestones are all represented. The red sandstones are the dominant type. They contain clay pellets, small cavities with calcite crystals, and much calcite in the form of minor flakes or rhombs within the mass of the rock. It is these same red marly sandstones which contain a great profusion of reptilian bones, disseminated throughout the rock as minor fragments, but occasionally displaying small jaw bones with the teeth attached. The inorganic limestones and paper shales contain no such remains.

CONCLUSION

On available evidence, minor outlying occurrences of littoral Trias appear to be confined to a zone south of the boundary of the main Triassic outcrops and up to one-third of a mile in width. The structural or erosional features within the Carboniferous Limestone, and in which they are preserved, show great variation within short distance. This is paralleled by an equally varied assortment of sediments or accumulations filling these cavities. Even so, the most prevalent accommodating structure is a major joint of fault fissure and the dominant filling material is a red marly sandstone. In the examples investigated,

fragments of reptilian bones are confined to the red marly sandstones where these occur in cavities or fissures which originally had restricted links with overhead sedimentation.

For his interest in the production of this paper and comments on its form the writer is indebted to Dr. F. J. North, Keeper of the Geological Department, National Museum of Wales.

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BRYN BACH,
BETTWS, NR. BRIDGEND,
GLAMORGAN.

ANNOUNCEMENT

INTERNATIONAL GEOLOGICAL CONGRESS, 19TH SESSION, ALGIERS, 1952

Arrangements for special currency allotments for attendance at the Session in Algiers have been discussed with the Bank of England.

Persons resident in the United Kingdom who propose to attend the Session should apply through their own bankers, quoting Bank of England reference 1/397 EC 831/RG.11 on a form T.2 which is obtainable at any bank, for special currency allotments calculated at £5 per day for the period of the actual Session and of any associated geological excursions in which they intend to take part. The serial number, short title, and dates of each excursion should be stated.

The exact dates of the excursions are to be announced in the Third Circular from Algiers, and the General Secretary in Algiers states that this circular is due to be delivered to prospective members in the United Kingdom on or shortly after 20th May.

It is recommended that applications shall be submitted as soon as possible and by **18th June** at the latest, since the total number of persons to whom special currency allotments may be made is limited to 60. For the same reason, applicants are advised that they should not finally commit themselves to expenses for travel or in Algiers until they know that their applications for currency allotments have been approved.

Applications submitted later than 18th June may be considered provided the maximum of 60 has not been reached by that date.

Notes on some Pleistocene Sections at Barrington, Cambridgeshire

By B. W. Sparks

Abstract

Valley fill exposed in chalk pits at Barrington consists of two beds, which differ markedly in lithology and in the nature of the molluscan fauna contained in them. The lower bed is thought to predate the Boulder Clay, which caps the high ground, and the upper bed is considered to have been derived from the Boulder Clay. The lower bed, a chalk solifluxion, apparently spread into the Cam valley and covered the famous *Hippopotamus* bed. Both the *Hippopotamus* bed and the present depth of the Cam valley, therefore, probably predate the Boulder Clay.

Introduction

BETWEEN Haslingfield and Barrington a narrow steep-sided ridge composed mainly of Lower Chalk extends almost to the left bank of the River Cam. It forms a spur of the "200-foot" plateau, which occupies much of the area between the Cam and the Ouse and, like that plateau, is capped by Boulder Clay. The southern flank of the ridge is notched by a series of small dry valleys, which descend steeply to the 100/75-foot terrace at the front of which Barrington is sited. Sections through these valleys and the deposits filling them are admirably displayed in Eastwood's chalk pit, which is cut into the lower part of the ridge half a mile north of Barrington Church (Text-fig. 1).

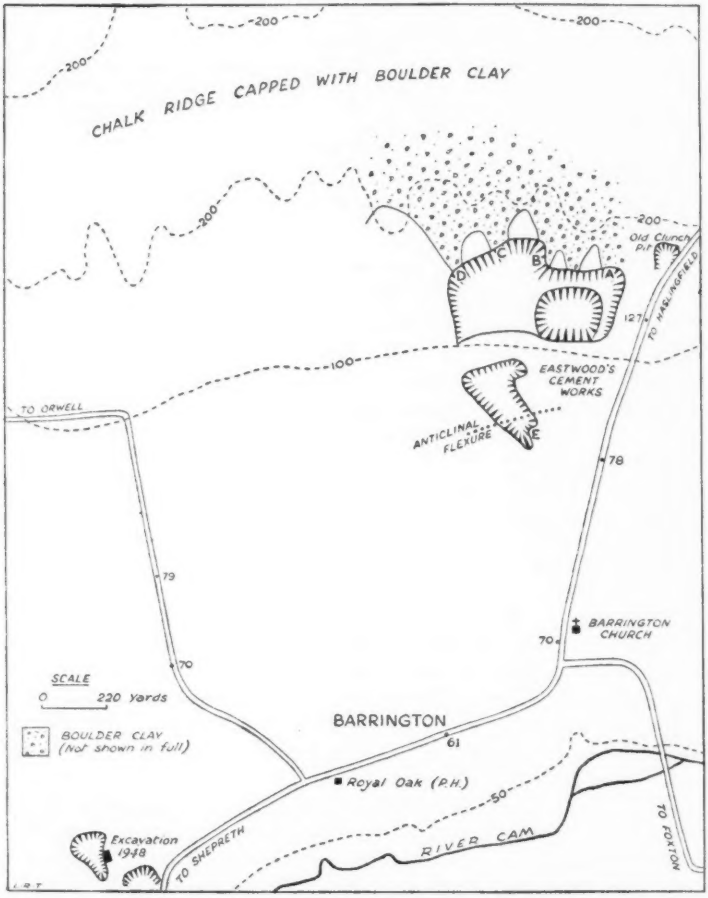
The Lithology of the Sections

The main chalk face exposes sections through four of the valleys (A, B, C, and D in Text-fig. 1), while the fifth section, E, is at the southern end of the Chalk Marl pit to the south. It may be located easily on the small east–west section of the face a few yards south of the minor anticlinal flexure, which exposes Cambridge Greensand and Gault in the floor of the pit.

The four northern sections vary so little that one description may be applied to them all: it is based mainly on sections B and C, as section D does not expose the full depth of the infill and section A has certainly been disturbed by the dumping of unwanted chalk. Illustrations of sections B and C are shown in Text-fig. 2, which is based on field sketches and photographs.

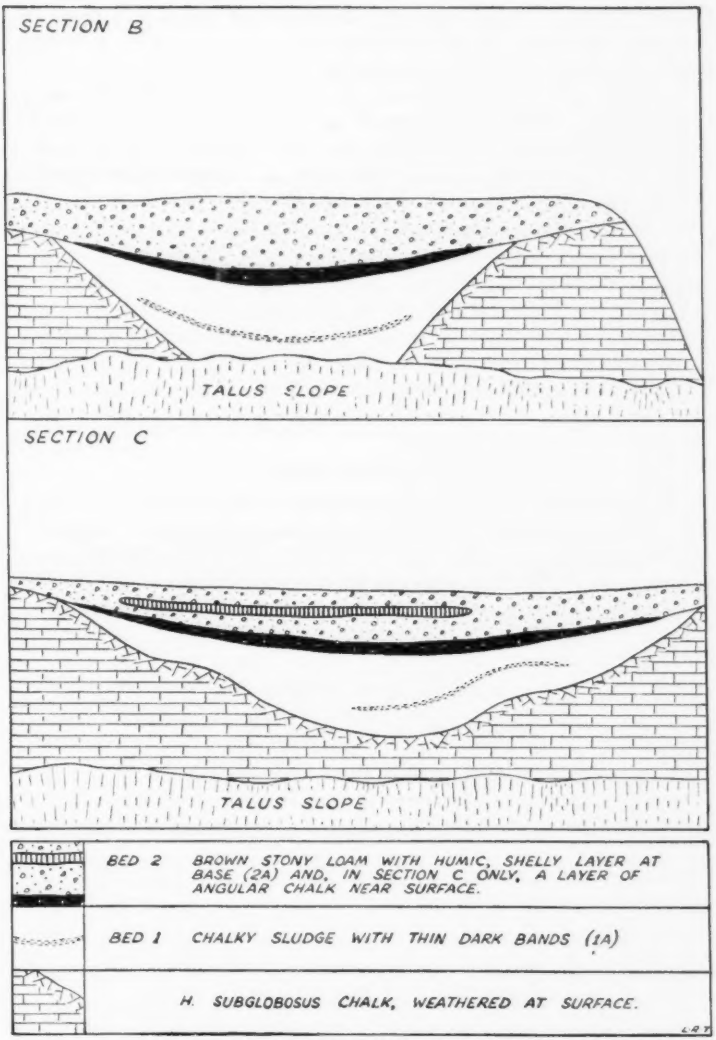
The lower bed (Bed 1 in Text-fig. 2) is composed almost entirely of rounded chalk pellets, up to one inch in diameter but generally much smaller, set in a matrix of finely divided chalk. In the field, its extent is shown very clearly by the manner in which it retains the marks of the teeth of the mechanical excavators used in the pit.

Below there is a gradual transition from highly weathered chalk to unweathered chalk of the *H. subglobosus* zone. In sections B and C the bed is interrupted by one or two bands, up to six inches in thickness,



TEXT-FIG. 1.—Map of pits near Barrington. The Boulder Clay is shown only where augering proved it to a depth of at least 3 feet ; it includes the Holocene valley fill (Bed 2) as far as the main face of Eastwood's pit.

which are darker in colour as a result of the presence of humus and occasional charcoal fragments (Bed 1A in Text-fig. 2). The whole of Bed 1 contains few erratics, those found being white patinated flint chips and rounded pebbles of quartz and quartzite.


SECTION B
TALUS SLOPE
SECTION C
TALUS SLOPE
BED 2 BROWN STONY LOAM WITH HUMIC, SHELLY LAYER AT BASE (2A) AND, IN SECTION C ONLY, A LAYER OF ANGULAR CHALK NEAR SURFACE.
BED 1 CHALKY SLUDGE WITH THIN DARK BANDS (1A)
H. SUBGLOBOSUS CHALK, WEATHERED AT SURFACE.

TEXT-FIG. 2.—Sketch sections of infilled valleys.

Bed 2, completely different in lithology, is a brown, stony loam, which overlaps Bed 1 in all sections. At its base is a dark, humic band packed with shells (Bed 2A in Text-fig. 2), and containing fewer chalk fragments than the main mass of the loam above. In section C

only, a layer of large angular chalk fragments occurs at a depth of approximately two feet from the surface. As it is probably of human origin it is left out of the remainder of this discussion.

Section E, at the southern end of the pit, is comparable, but Bed 1 is reduced in thickness from 7–10 feet to 5 feet, and Bed 2 is only 2 ft. 6 in. compared with the 7–11 feet of the northern sections. Bed 1, difficult to distinguish from Chalk Marl, is of a texture slightly different from that of the equivalent bed of the other sections. At its base is a medium to fine chalk-and-flint gravel with erratics comparable with those of Bed 1 in the northern sections. The upper part, however, is a consolidated chalk paste, very much like Chalk Marl but softer. The overlap of Bed 2 is more pronounced than in the northern sections. Unlike the latter, which occupy surface valleys, section E has no reflection in the surface of the terrace on which it is found, but it is obviously a continuation of one of the northern sections, as traces of the infill can be seen in the floor of the pit in several places.

The Mollusca

It became quickly obvious that sections A to D showed an identical fauna and, accordingly, they are combined in the list below. Section E is treated separately, as its fauna is somewhat different. Actual numbers of identified shells are recorded as being the most precise way of expressing the frequency of their occurrence, although Arionid granules, many of which occur in a single slug, are treated descriptively.

Fauna of Bed 1 (Pleistocene)

	Sections A–D. (Bed 1).	*Sections A–D. (Bed 1A).*	*Section E.*
Lymnaea (*Galba*) *truncatula* (Müller)	—	—	66
Lymnaea (*Stagnicola*) *palustris* (Müller)	—	—	5
Planorbis (*Anisus*) *leucostoma* Millet	—	—	124
Succinea (*Quickella*) *arenaria* Bouchard-Chantereux	—	—	145
Succinea (*Oxyloma*) *pfeifferi* Rossmässler	—	—	90
Vertigo antivertigo (Draparnaud)	—	—	6
Vertigo pygmaea (Draparnaud)	—	—	7
Vertigo parcedentata (Al. Braun)	—	—	180
Pupilla muscorum (Linné)	85	102	69
Vallonia costata (Müller)	36	62	—
Vallonia pulchella (Müller)	15	71	108
Cochlicopa lubrica (Müller)	23	41	24
Clausilia sp.	—	—	1
Trichia hispida (Linné)	139	12	16
Helicella (*Xeroplexa*) *geyeri* (Soós)	32	19	—
Helicella (*Helicella*) *itala* (Linné)	1	—	—
Punctum pygmaeum (Draparnaud)	9	12	12
Euconulus fulvus (Müller)	5	10	13
Retinella (*Perpolita*) *radiatula* (Alder)	5	5	6
Vitrina pellucida (Müller)	12	5	—

	Sections A–D. (Bed 1).	*Sections A–D. (Bed 1A).*	*Section E.*
Arion sp.	common	common	common
Agriolimax spp.	23	20	15
Pisidium cinereum Alder	—	—	7
Pisidium obtusale (Lamarck)	—	—	5
Pisidium nitidum Jenyns	—	—	1

FAUNA OF BED 2 (HOLOCENE)

	Sections A–D. (Bed 2A).	*Sections A–D. (Bed 2).*	*Section E. (Bed 2A).*
Pomatias elegans (Müller)	251	20	12
Acme fusca (Montagu)	1	—	—
Carychium tridentatum (Risso)	326	15	11
Lymnaea (Galba) truncatula (Müller)	—	—	2
Vertigo pygmaea (Draparnaud)	16	1	2
Truncatellina cylindrica (Férussac)	—	5	—
Pupilla muscorum (Linné)	135	41	2
Acanthinula aculeata (Müller)	14	1	2
Vallonia costata (Müller)	249	94	2
Vallonia pulchella (Müller)	1	7	6
Vallonia excentrica Sterki	106	118	2
Cochlicopa lubrica (Müller)	23	9	—
Azeca goodalli (Férussac)	1	—	—
? *Ena montana* (Draparnaud)	4	—	—
Clausilia bidentata (Ström)	13	3	1
Cochlodina laminata (Montagu)	20	3	—
Cecilioides acicula (Müller)	—	21	2
Arianta arbustorum (Linné)	1	—	1
Helix (Cepaea) nemoralis Linné	32	9	8
Trichia hispida (Linné)	29	16	4
Helicella (Helicella) itala (Linné)	41	77	4
Punctum pygmaeum (Draparnaud)	1	1	—
Discus rotundatus (Müller)	111	9	2
Vitrea crystallina (Müller)	7	—	—
? *Oxychilus cellarius* (Müller)	3	1	—
Oxychilus helveticus (Blum)	1	—	—
Retinella (Perpolita) radiatula (Alder)	8	3	—
Retinella (Aegopinella) pura (Alder)	2	2	—
Retinella (Aegopinella) nitidula (Draparnaud)	26	3	2
Arion sp.	abundant	common	abundant
Limax spp. & *Agriolimax* spp.	30	6	14

The number of shells in the different beds is large enough for fairly accurate estimates of their environmental conditions to be formed. Climatic ranges and habitats have been derived mainly from Ellis (1926), Geyer (1927), and Ehrmann (1933). Detailed notes on some of the species will be found at the end of the paper.

Bed 1 is of Pleistocene age: both the geological relationships, which are discussed below, and the nature of the mollusca indicate this

conclusion. The shells, with a few exceptions, are all capable of withstanding the climatic conditions experienced to-day in the north of Scandinavia or in the Archangel district. On the other hand, they are all capable of living as far south as Central Europe, but the lack of definitely southern forms is significant, although this evidence is admittedly negative. Further, the lithology of Bed 1 clearly suggests a sludging of chalk waste under periglacial conditions. The differences between the shells of the northern sections and section E merely point to a variation in local conditions, which were evidently much damper on the low ground than higher up the valleys. The dark bands (1A) have a greater concentration of shells than the main part of the bed, but the species are the same : any amelioration of climatic conditions must have been extremely slight.

The apparently anomalous shells are *H. itala* and *Clausilia* sp. The first, however, was listed by Kennard (1924) as late Pleistocene, Boreal, and, if the *Clausilia* is *bidentata*, its presence is not surprising, as it is found within the Arctic Circle in Norway at the present time. Moreover, it is quite possible that some snails adapted themselves to a refrigeration : indeed, " . . . it would appear that a large proportion of the molluscan species were able to survive the rigours of the cold period " (Kennard, 1924, p. 94).

Far more significant is the abundance of *Vertigo parcedentata* in section E. This minute species, now probably extinct in Britain, belongs to Pilsbry's *V. modesta* group, which, in distribution, is " circumpolar, numerous in races and individuals above the parallel of 60°, and extending south at increasing elevations . . ." (Pilsbry, 1918–1920, p. 72). It is a common shell in German periglacial deposits, the fauna of which appears to be no colder than that found at Barrington (compare the lists in Steusloff, 1938).

Bed 2 is of Holocene age. The fauna is very different from that of Bed 1 and more nearly resembles the modern fauna, although it is by no means identical. The shells from the basal humic layer, which would appear to be an old soil, indicate conditions at least as warm as those now prevailing. The presence in great numbers of *Pomatias elegans*, which prefers the loose, friable soil of calcareous districts ; of *Vallonia excentrica*, which avoids woodland ; of xerophiles such as *Helicella itala* and *Pupilla muscorum*, indicates open country. But such species as *Discus rotundatus*, *Clausilia bidentata*, and *Cochlodina laminata*, which are all commonly found beneath the bark of rotting logs, contradict this conclusion. One must presume the area to have been one of mixed woodland or scrubland and open spaces. An increasing dryness is betrayed by the decline up through the loam of the damp-loving forms. The base of Bed 2 cannot be precisely dated, but the complete absence of *Helix* (*Cryptomphalus*) *aspersa*, *Monacha cantiana*,

Trichia striolata, *Helicella* (*Candidula*) *caperata*, *Helicella* (*Candidula*) *gigaxii* and *Helicella* (*Cernuella*) *virgata*, all of which are found alive in the immediate neighbourhood, indicates an early Holocene age, as all these species spread from various parts of Southern England in Roman and post-Roman times (Kennard, 1923). It is probable that Bed 2A dates from the damp Atlantic phase of post-glacial times.

Interpretation of the Sections

It is surprising that, although the valleys extend almost to the crest of the ridge, the lower bed should be of such an unadulterated chalky consistency. It contains no traces of brown loam and, as far as is known, no Jurassic erratics or fossils. It is inconceivable, without recourse to numerous unlikely assumptions, that the valleys and the lower chalky sludge were formed after the Boulder Clay had been deposited on the top of the ridge. The valleys must predate the Boulder Clay and may well represent a phase of melt-water scouring and solifluxion immediately prior to the onset of the ice sheet which deposited the Boulder Clay. The presence of some erratics is of no great significance. There was probably an earlier glaciation of the district, and, even without this possibility, such durable pebbles as flint and quartzite may have survived from ancient river gravels. If these arguments are correct, it follows that the Cam valley must have been excavated to something like its present depth before the deposition of the Boulder Clay, as the chalky sludge of Bed 1 flowed down slopes very much like the present ones.

The darker bands in Bed 1 represent slight halts in deposition, during which the fauna became more abundant, some vegetation appeared and a thin soil profile developed. The general climatic conditions cannot, however, have changed greatly. The peculiar nature of the valley floor in section C and the undulation of the dark band are not easily explicable other than on some vague hypothesis of peculiarity in the flow of the sludge.

The Boulder Clay presumably mantled both high ground and low, but in its initial semi-fluid state is slipped off the steeper slopes into the valleys, where it was resorted by the swollen streams of periglacial conditions. The next event, of which evidence exists at Barrington, is the cutting of the terrace at 100–75 feet O.D. This erosional feature is clearly younger than Bed 1, as it truncates that bed and the Chalk Marl indifferently : its precise relation to the Boulder Clay is unknown, but a later age for the terrace is suspected. Considerably later, soil creep and rainwash led to the slow downhill movement of the Boulder Clay into the valleys and on to the terrace, but it does not appear to have advanced much farther than the back of the terrace. If the Boulder Clay had capped the ridge during the deposition of Bed 1,

that bed should have been lithologically similar to Bed 2. It is, in fact, completely different.

The Section at Barrington Village

A small portion of the face of Mr. Cardo's well-known pit was cleared under the direction of Professor W. B. R. King for the International Geological Congress of 1948 and the following section exposed :—

(4) 3–4 feet of chalky sludge with few flints. A pocket of red loam was visible at the surface.

(3) 6 inches of coarse, ungraded, round and angular quartz and flint pebbles.

(2) 2 feet to 2 ft. 6 in. of chalky sludge with sand grains resembling (4) above.

(1) 6 inches of mixed sand and gravel.

The whole is underlain by Chalk Marl.

The first impression given by the section is its lithological similarity to the lower chalky sludge (Bed 1) of Eastwood's pit, but the list of shells published by Mrs. McKenny Hughes (1888) and revised later by Kennard and Woodward (Marr, 1919 ; Kennard and Woodward, 1922) is very different from the fauna of the bed in Eastwood's pit. None of the papers states the horizons from which the shells came, and Kennard and Woodward (1922) suggested that more careful collecting might show the deposit to be of two ages. Unfortunately, the opportunity to do this has long passed, but a number of shells were found in the 1948 excavation and they are listed below, the numbers referring to the beds tabulated above.

	Bed 1.	*Bed 2.*	*Bed 3.*	*Bed 4.*
Bithynia tentaculata (Linné)	—	—	2	—
Valvata piscinalis (Müller)	—	—	—	56
Lymnaea (*Galba*) *truncatula* (Müller)	2	—	—	11
Lymnaea (*Stagnicola*) *palustris* (Müller)	—	—	1	1
Lymnaea (*Radix*) *peregra* (Müller)	—	—	—	32
Planorbis (*Anisus*) *leucostoma* Millet	2	—	—	13
Planorbis (*Anisus*) *vortex* (Linné)	—	—	—	8
? *Succinea* (*Quickella*) *arenaria* Bouchard-Chantereux	1	—	1	—
Succinea (*Oxyloma*) *pfeifferi* Rossmässler	—	—	1	17
Vertigo antivertigo (Draparnaud)	—	—	—	1
Pupilla muscorum (Linné)	—	1	2	35
Vallonia costata (Müller)	—	—	1	4
Vallonia pulchella (Müller)	1	—	—	4
Cochlicopa lubrica (Müller)	—	—	—	1
Trichia hispida (Linné)	5	4	12	66
Helicella (*Xeroplexa*) *geyeri* (Soós)	2	—	—	—
Helicella (*Helicella*) *itala* (Linné)	6	—	7	—

	Bed 1.	*Bed 2.*	*Bed 3.*	*Bed 4.*
Retinella (*Aegopinella*) *nitidula* (Draparnaud)	—	—	—	1
Arion sp.	—	—	rare	—
Agriolimax spp.	3	—	9	22
Pisidium amnicum (Müller)	—	—	1	3
Pisidium cinereum Alder	—	—	5	6
Pisidium subtruncatum Malm	—	4	2	25

As with Bed 1 at Eastwood's pit, these shells could have withstood the rigours of the present climate of the northern half of Scandinavia. When compared with Kennard's lists the absence of the warmer forms is striking. Of these, *Corbicula fluminalis* is stated by Kennard to have been found only in the basal bed where it was associated with *Hippopotamus*. From an examination of pieces of the basal bed preserved in the Sedgwick Museum, it seems unlikely that the bed was exposed in the new section. Other southern forms, such as *D. rotundatus*, *A. aculeata*, *H. nemoralis*, *T. minutissima*, and the single *P. elegans* found by Mrs. Hughes may have come either from the basal bed or from the vicinity of the surface.

McKenny Hughes (1911, 1916) stressed the absence of Jurassic material in Cardo's pit, and the 1948 section did not reveal any. The whole exposure is probably to be correlated with the lower bed of similar lithology in Eastwood's pit. The faunal changes indicate merely a change from drier to damper, and finally to stream conditions. The lithological changes are small and consist of a change from chalk pellets in a matrix of chalk paste to chalk paste, a change such as might be expected to have occurred in any solifluxion that travelled some distance from its source. The *Hippopotamus* bed, therefore, is presumed to have been formed during an interglacial period and the uneroded parts of it buried, at the onset of the next glaciation, by a chalk sludge deriving from the ridge to the north.

Conclusion

From these considerations of the physical geography, lithology, and mollusca of the Barrington sections, the following sequence of events would appear to involve the fewest improbable assumptions :—

(1) The Cam valley was excavated to its present depth and the *Hippopotamus* bed, an interglacial deposit, laid down in it.

(2) With the approach of a glacial period, a chalk sludge spread from the ridge north of Barrington and covered the uneroded parts of the *Hippopotamus* bed.

(3) The glaciation deposited Boulder Clay over the whole region, but it was preserved only on the ridge.

(4) After an unknown period of time the 100/75-foot terrace was eroded by the Cam.

(5) Commencing in Holocene times, soil creep caused the Boulder Clay capping the ridge to move slowly downhill as far as the back of the terrace. The movement may have been accelerated by man, as the shells indicate a slight desiccation such as might be expected to have followed clearance for cultivation.

At present the sequence can apply only to Barrington, but the hope of its extension to other areas is increased by the remarkable similarity of the sections in the dry valleys at Pegsdon, Bedfordshire, some twenty-five miles away (Lewis, 1949).

Notes on Certain Species of Mollusca

The nomenclature used in this paper is that advocated by modern authors such as Watson (1943), and thus some of the names are different from those used in older papers on the Cambridge Pleistocene.

(1) *Carychium tridentatum* (Risso) is a distinct species and not a variety of *Carychium minimum* (Müller), in which it is included in the earlier records.

(2) *Truncatellina cylindrica.* The Barrington specimens are *T. cylindrica* itself, formerly known as *T. minutissima* (Hartmann), and not the subspecies *T. cylindrica britannica* Pilsbry.

(3) *Cecilioides acicula* is a borrowing species and the shells recorded from Bed 2 in Eastwood's pit may be recent.

(4) *Ena montana.* Only apical fragments were found at Barrington, but they more closely resemble *E. montana* than *E. obscura.* Although *E. montana* is now extinct in the county, it is not uncommon in some of the gravels.

(5) *Succinea* (*Quickella*) *arenaria.* Earlier records of the Cambridge Pleistocene list *Succinea oblonga*, but it is now known that this includes two distinct species, *Succinea* (*Quickella*) *arenaria* Bouchard-Chantereux and *Succinea* (*Hydrophyga*) *oblonga* Draparnaud (Quick, 1933). The former is recorded living mainly from maritime localities, but Dr. Quick, who kindly examined the shells of this species from Barrington, informs the writer (*in litt.*) that it has also been found alive in the centre of Ireland. Thus, its presence at Barrington is less surprising.

(6) *Helicella* (*Xeroplexa*) *geyeri* (Soós). The occurrence at Barrington of this species is the first record of it in the British Isles. It greatly resembles *Helicella* (*Helicopsis*) *striata* (Müller) in shell characteristics but not in anatomy. *H. striata* has been recorded from the Pleistocene of Trumpington and Grantchester, where it is found associated with a very different fauna from that found with *geyeri* at Barrington. The exact distribution of these shells is unknown, due to their having

been confused, but *H. geyeri* is known to be living in the comparatively cold climate of the South Baltic. *H. geyeri* (= *H. striata* var. *minor* Geyer) is stated by Kennard and Woodward (1922) to be the characteristic form of the German *loess* and, at Barrington, it is associated with another typical *loess* shell, *V. parcedentata*. Whether *geyeri* has been confused with *striata* in Britain can only be decided after a careful examination of the shells recorded from other localities as *H. striata*. All that can be said at present is that the records of *H. striata* from Grantcester and Trumpington, Cambridgeshire, are correct.

(7) *Vertigo pygmaea*. One specimen from Bed 1 in section E is very like *Vertigo heldi* Clessin, but, as the latter is probably an abnormal form of *V. alpestris* or *V. pygmaea* (Pilsbry, 1918), it is not listed separately. It is perhaps significant that one specimen of *V. antivertigo* from the same bed shows a similar elongation. Adverse climatic conditions, prolonging the time taken by the snail to reach maturity, may have been responsible. The cold species of *Vertigo* are, in general, larger than the more southern species.

(8) *Vertigo parcedentata* (Al. Braun). There is considerable confusion concerning the European species of *Vertigo* related to *V. arctica* (Wallenberg). The main doubt is whether *V. genesii* Gredler and *V. parcedentata* (Al. Braun) are identical and, if they are, as to which name should be used. *V. parcedentata* was originally described as a weakly denticulate form from the German *loess* (Braun, 1847). *V. genesii* was originally defined as an edentulate species, but Lindholm (1925) included the four-toothed forms as a subspecies and Geyer (1927) describes the shell as possessing none to four teeth. The Pleistocene shells have usually been called *V. parcedentata* and the modern ones *V. genesii*. Steusloff, who has written at some length on the species, originally held that they could be distinguished if large groups of the shells were examined (1938), but later came to the conclusion that they are virtually indistinguishable (1942). Whatever the truth, it would appear better to retain the name based on the Pleistocene shells for the Barrington specimens. If the shells prove to be identical, *V. parcedentata* will still be the valid name as it is older than *V. genesii*.

Originally it was thought that some of the *V. parcedentata* from Barrington were *V. lilljeborgi* Westerlund, but they are probably no more than slightly inflated *V. parcedentata* with four weak teeth. The shells of the species show quite a large variation of form.

(9) *Trichia hispida*. The Holocene specimens from Eastwood's pit approach the form recorded by Kennard as *T. liberta* (Westerlund), but there is considerable doubt whether *T. liberta* is a distinct species.

I must express my thanks to Mr. A. E. Ellis for examining the *Pisidia*, to Dr. H. E. Quick for examining the *Succineae* and slug

shells, and especially to Mr. Hugh Watson for his unfailing kindness in examining difficult species and for his advice on nomenclature.

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On some Spore Specimens from British Upper Carboniferous Coals

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Abstract

Eight spore types from Upper Carboniferous coals of Britain are described and figured, and their stratigraphical distribution and possible relationships are discussed. One new genus and five new species are instituted.

Introduction

Investigations of the stratigraphical distributions of Carboniferous microspores in a number of British Coalfields are in progress. During these studies a number of species have been found to have limited time-ranges or to show marked variations in abundance in different stratigraphical subdivisions. Most of these species have been previously recorded in Carboniferous coals from Great Britain or elsewhere, but others are either undescribed or described only cursorily and with inadequate illustration. In view of their possible importance in problems of coalfield correlation it is considered desirable that full descriptions and illustrations should be recorded.

New and unnamed species have been assigned as far as possible to the form genera proposed by Schopf, Wilson, and Bentall in 1944. To avoid multiplication of genera in the purely descriptive phase of this work, I have attempted wherever possible to assign a particular species to one of the original genera even at the risk of unduly extending these.

The type material of all these species was macerated with Schultze solution and alkali, the time of maceration depending on the rank of the coal under treatment. Variations in the maceration technique slightly affect the size and general appearance of the isolated spores, but it is considered that all the spores described below are sufficiently characteristic to be readily identifiable in material macerated by any of the usual techniques.

Descriptions

Genus Densosporites (Berry, 1937), emend. Schopf, Wilson, and Bentall, 1944.

Densosporites solaris sp. nov., Text-fig. 1*a*–1*b*.

Type Material.—Houghton Thin seam at 766 ft. 5 in. Wentbridge No. 2 bore-hole, Yorkshire.

Diagnosis.

The spore is oval to subtriangular when compressed in proximo-distal orientation. In lateral compressions the proximal side is seen to be tetrahedral and the distal hemispherical. It consists of a small central

body, conforming in general outline to the outer margin of the spore, surrounded by a narrow thickened equatorially attached flange.

Mean dimensions of thirty measured specimens : Total maximum diameter : 49μ (limits 39μ–65μ), maximum body diameter 32μ, flange 7μ–10μ in width.

Trilete suture markings are visible in some specimens when the lips of the scars are turned slightly outwards and extend to the inner periphery of the flange.

The exine of the central polar region is thin, finely punctate, and ornamented with small tubercles. The outer periphery of the flange is indented and prolonged into flattened spinose projections about 4μ in length. Similar projections also occur on the proximal and dorsal surfaces of the flange.

Discussion.

The spore resembles an extreme variant of the species *Densosporites indignabundus* (Loose) S.W. & B., and had it been identified only in association with definite members of that species its separation would probably be unjustified. *D. solaris*, however, is very abundant in certain coal seams which do not yield a single specimen referrable without doubt to *D. indignabundus*. It is distinguished from the latter species by its smaller size, its narrower flange relative to the diameter of the body, and the lack of significant variations in flange ornament.

Occurrence.

Abundant in a few seams in the uppermost part of the Westphalian B in Yorkshire and Nottinghamshire, and also identified in coals at similar horizons in South Derbyshire and Staffordshire (Cannock Chase).

Genus RETICULATISPORITES (Ibrahim) emend. Schopf, Wilson, and Bentall, 1944.

Reticulatisporites mediareticulatus Ibrahim, 1933, Text-fig. 1*c*.

1933 *Reticulatisporites mediareticulatus* (Ibrahim).
1944 *Reticulatisporites mediareticulatus* (Ibrahim), Schopf, Wilson, and Bentall.
1950 *Reticulatisporites mediareticulatus* (Ibrahim), Knox.

Hypotype Material.—High Hazel seam, Thorne Colliery, Yorkshire.

Description.

Spore is elliptical or subcircular when compressed in lateral or semi-lateral view, its usual mode of preservation.

Mean dimensions (thirty measured specimens) 47μ × 41μ.

Range, 56μ × 48μ – 40μ × 34μ.

The character of the tetrad markings has not been observed. The exine, normally about 1μ thick, is differentially thickened by a system

of well defined ridges about 2μ wide and 2μ–3μ deep which divides the surface into very characteristic, regular, hexagonal lacunae about 12μ–14μ in diameter. In some specimens the exine of the lacunae is finely punctate.

In planes of compression it can be seen that the reticulations do not cover the whole surface of the spore but that a narrow zone of the exine is unornamented. This presumably represents the contact area on the proximal face.

Discussion.

The characteristic regular cell-shaped thickenings of the exine, and its very limited size variations, enable this spore to be identified without difficulty in separations in which it occurs. It is equivalent to F2 of Raistrick and Knox and F1 of Millott and is regarded by Knox as conspecific with *Reticulatisporites mediareticulatus* (Ibrahim). It is possible that this species is not a spore sensu stricto but a pteridosperm pollen grain. Pollens of similar size and ornament have been described by Benson from the anther sacs of *Telangium scotti*.

Occurrence.

R. mediareticulatus shows unusual features of distribution. It is abundant in narrow bands of coal in some Yorkshire seams (the Stanley Main coal, Barnsley, and Flockton Thick for example), and absent or very rare in the remainder of the same seam. Such bands are often laterally persistent over wide areas and form a useful correlation guide. It appears to be confined to seams from the Westphalian B and upper part of the Westphalian A, in Yorkshire and Nottinghamshire, South Derbyshire, North and South Staffordshire, Lancashire, and North Wales.

Reticulatisporites tortuosus sp. nov., Text-fig. 1*d*.

Type Material.—Wheatworth seam at 907 ft. 11 in. Wentbridge No. 2 bore-hole, Yorkshire.

Diagnosis.

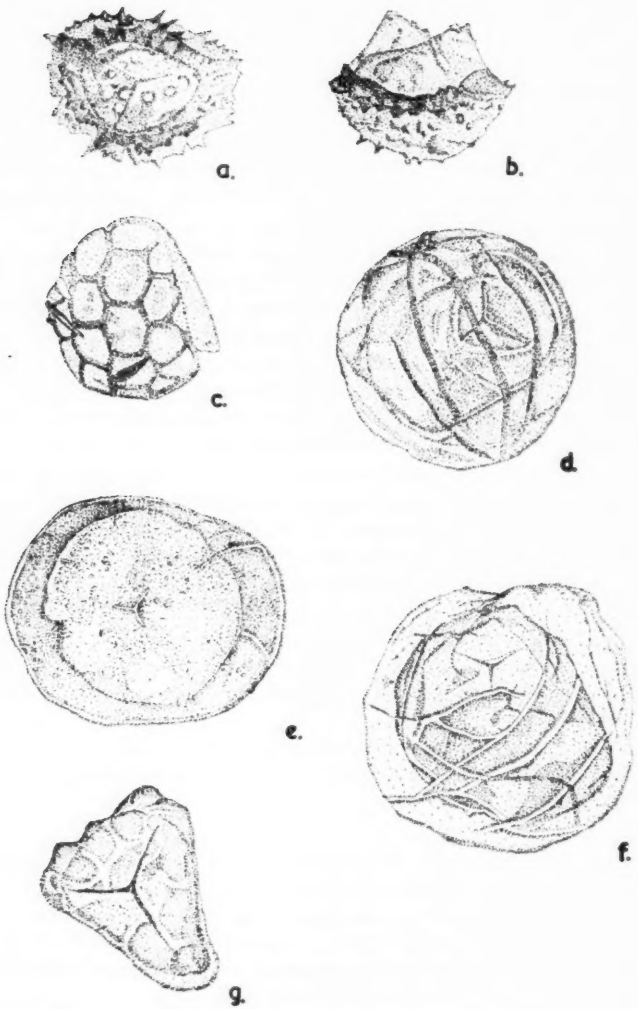
The spore is circular or subcircular when compressed. Mean diameter of thirty measured specimens 86μ. Limits 65μ–100μ.

In favourably preserved specimens faint trilete markings can be observed. The rays are short (about $\frac{1}{3}$ radius in length), closed, and the contact area delimited by three narrow arcuate exine thickenings joining the extremities of the three rays of the scar.

The exine is ornamented by two major sets of spiral thickenings (1μ–3μ broad) which intersect with one another and divide the surface into roughly quadrilateral areas about 10μ–20μ wide.

Discussion.

R. tortuosus was included by Raistrick in his type G1 and by Millott and Knox in their type G. Specimens which conform rigidly to the



TEXT-FIG. 1.—(*a*) *Densosporites solaris* sp. nov., proximal view.
(*b*) *D. solaris*, lateral view.
(*c*) *Reticulatisporites mediareticulatus* Ibrahim, lateral view.
(*d*) *Reticulatisporites tortuosus* sp. nov., semi-proximal view.
(*e*) *Endosporites ovatus* (Knox), proximal view.
(*f*) *Endosporites costatus* sp. nov., semi-proximal view.
(*g*) *Triquitrites sculptilis* sp. nov., proximal view.
Magnification × 500.

specific diagnosis are, however, relatively uncommon and are invariably associated with spores of similar size and form, but with a very much more complex ornament. In these the spiral thickenings predominate, but the intra-mural quadrilateral areas are further subdivided by a second series of much more irregular ridges which give the ornament a mesh-like appearance. For present purposes such spores have been included under *R. tortuosus* sp. nov., but if future subdivision is considered desirable it is probable that they should be assigned to *R. irregularis* (Kosanke) or in some cases to *Punctatisporites foveatus* (Kosanke).

Occurrence.

R. tortuosus has been found in most seams from the Westphalian B and C and occasionally from coals in the upper part of the Westphalian A in Yorkshire, Nottinghamshire, South Derbyshire, North Staffordshire, Lancashire, North Wales, and Scotland.

Genus ENDOSPORITES Wilson and Coe, 1940.

Endosporites costatus sp. nov., Text-fig. 1*f*.

Type material from seam at 719 ft. 3 in., Manton Colliery, No. 4 shaft sinking, Nottinghamshire.

Diagnosis.

Spore is circular or sub-circular in proximo-dorsal orientation and consists of a circular body surrounded by a relatively narrow translucent hollow bladder.

Mean dimensions of thirty measured specimens : total diameter 79μ ; body diameter 60μ.

Limits total diameter : 60μ–104μ ; body diameter 46μ–85μ.

Trilete suture markings are clearly defined in full proximal view. The rays are usually about half body radius in length and sometimes completely opened to form a triangular opening at the proximal pole.

The body exine and bladder are similarly but rather variably ornamented. The most usual form of ornament is a series of ridges 2μ–3μ wide and 2μ deep, which appear to encircle the spore spirally, occasionally anastomosing to divide the surface into irregular shaped angular areas. Some specimens, however, show little evidence of differential thickening of the exine. Arcuate folding of the exine is common particularly along the margin of the inner spore body.

Discussion.

The species, as defined, possibly includes specimens referable to Ibrahim's *Zonalessporites rugatus* and *Reticulatisporites reticulaformis*, but it is impossible to be certain of this from the author's descriptions and figures. The ornament is unusual for *Endosporites* and the assignation of the spore to that genus must be regarded as tentative.

Occurrence.

E. costatus is fairly common in seams from the Westphalian C and Westphalian B of Yorkshire and Nottinghamshire, South Derbyshire, North Staffordshire, Lancashire, and North Wales and has been identified in South Wales and Cumberland coals of similar age.

Endosporites ovatus (Knox, 1950), Text-fig. 1*e*.

1950 *Planisporites ovatus* Knox.

1950 *Schulzospora rara* ? Kosanke.

Hypotype Material.—Seam of coal at 3,387 feet, Blacklake borehole, North Staffordshire.

Description.

This spore was described and figured by Knox in 1950 as *Planisporites ovatus* and designated as follows :—

" Oval, 80μ–150μ long. Triradiate mark $\frac{1}{3}$ radius, frequently open. Surface very finely granular."

The spore is usually oriented in full proximo-dorsal view and consists of a central spore body surrounded by an elliptical hollow bladder.

Mean dimensions (thirty measured specimens) : total spore 81μ $\times$ 65μ ; body diameter 60μ.

Limits : total dimensions 105μ $\times$ 75μ – 70μ $\times$ 55μ. Body 48μ – 75μ.

Trilete sutures are usually visible, although occasionally indistinct, and sometimes open in a triangular rent at the proximal pole. The three rays are short.

The body and bladder are little differentiated although the body margin is marked by an annular thickening about 5μ wide which appears as a circular marking darker in colour than the remainder of the spore coat. Both body and bladder are similarly ornamented by indeterminate but probably finely punctate markings, which give the surface of the spore a characteristic " matt " appearance.

Discussion.

Knox's description makes no mention of the circular internal structure which Kosanke interprets, I think correctly, in his similar species as the spore body proper. For this reason I propose to transfer the British species to the genus *Endosporites* rather than accept Kosanke's new generic status without detailed comparison of the type material.

Occurrence.

The spore is occasionally common but usually rare in seams from the Westphalian A in Yorkshire and Nottinghamshire, South Derbyshire, North Staffordshire, Lancashire, and Scotland. It has not been seen in coals above the level of the Clay Cross Marine band in Yorkshire or its equivalents in other fields.

Genus TRIQUITRITES Wilson and Coe, 1940.

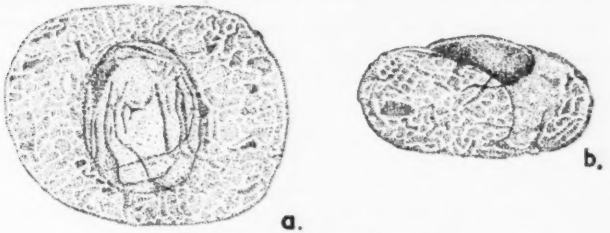
Triquitrites sculptilis sp. nov., Text-fig. 1*g*.

Type Material.—Seam at 670 ft. 10 in., Manton Colliery, No. 4 shaft sinking, Nottingham.

Diagnosis.

Spore subtriangular in proximo-dorsal orientation. Mean maximum median width (thirty measured specimens), 37μ. Limits, 25μ–45μ.

The exine is considerably thickened on the distal side and in a marginal zone about 2μ–4μ wide on the proximal side. The thickening



TEXT-FIG. 2.—*Florinites antiquus* Schopf.
(*a*) Distal view.
(*b*) Lateral view.
Magnification × 500.

is particularly exaggerated at the apices where it usually forms broadly rectangular projections about 12μ–17μ wide and 5μ–8μ long.

Trilete sutures are well marked and the rays extend to the inner periphery of the marginal thickened zone.

The exine is also sculptured into a number of shallow depressions about 10μ–14μ wide separated by narrow ridges. In high focus the exine has a reticulate appearance although the ridges are not sharply defined.

Discussion.

The sculpturing of the exine is unlike that of other species of Triquitrites but the strong differential thickening of the exine particularly at the apices leaves no doubt that the spore should be assigned to that genus. It resembles Ibrahim's *Reticulatisporites trigonus* in size and type of ornament, but that author makes no mention of any exinal thickening, and his figure shows a finer and more regular reticulation.

Occurrence.

T. sculptilis is fairly common in most seams examined from the Westphalian C of Yorkshire and Nottinghamshire, South Derbyshire, North Staffordshire, North Wales, Lancashire, and South Wales, and is very occasionally seen in seams from the uppermost part of the Westphalian B.

Genus FLORINITES Schopf, Wilson, and Bentall, 1944.

Florinites antiquus Schopf, Text-fig. 2*a*, *b*.
1944 *Florinites antiquus* Schopf, p. 58.
1950 *Florinites antiqua* Knox.

Hypotype material.—Kents Thick seam, Sharlston West Colliery, Yorkshire.

Description.

Schopf's original designation of this species (considered by him to be a conifer pollen) is an excellent one and so complete that no modifications are necessary or possible after examination of many hundreds of specimens from maceration residues of British coals.

The mean dimensions of fifty measured specimens are: bladder, $70\mu \times 56\mu$; body, 35μ long $\times$ 30μ broad.

The size distributions about these mean figures, when plotted in histogram form, are also closely similar to those indicated in Schopf's diagram (Schopf, Wilson, and Bentall, 1944, Fig. 5, p. 59).

There seems, therefore, no doubt that the hypotypes, which agree in all particulars with *F. antiquus*, are conspecific with that species.

Discussion.

F. antiquus, well known to previous British authors, was designated type 5 by Millott (1939), while some specimens at least were included by Knox in type 3K, subsequently identified by that author with *Endosporites globiformis* (Ibrahim), S., W., & B.

Occurrence.

It is very widely distributed in British coals. Relatively rare in seams from the Westphalian A, it becomes abundant in many coals in the Westphalian B and C. Millott states that it is not found below the level of the Crabtree seam in North Staffordshire.

Genus TORISPORA gen. nov.

The generic name *Torispora* is proposed for spores of unknown affinities having the following characters:—

Spores elliptical or subcircular when compressed in proximo-distal orientation, bilaterally symmetrical about the plane of the major axis when seen in full proximal or distal view. Distinctly monolete with a well marked suture line parallel to the major axis of the ellipse. The exine is differentially thickened, particularly at one extremity of the spore where it is expanded into a crescentic or broadly rectangular projection.

The thinner area of the exine is finely punctate and notched along the periphery.

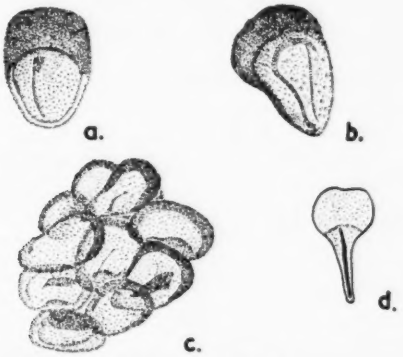
Torispora securis sp. nov. is designated as the type species.

Torispora securis sp. nov., Text-fig. 3*a–d*.

Type Material.—Big Vein seam, Norton Hill Colliery, Somerset.

Diagnosis.

The spore is elliptical when viewed in full proximo-distal orientation, but its tendency to preservation in other planes of compression leads to distortion in many specimens. Distinctly monolete, with a well marked straight or curved closed suture line parallel to the major axis of the spore. The exine is considerably thickened at one extremity



TEXT-FIG. 3.—*Torispora securis* gen. et sp. nov.
(*a*) Proximal view.
(*b*) Slightly distorted specimen in proximal view.
(*c*) Adherent mass of immature spores.
(*d*) Longitudinal section in plane at right angles to the proximal face.
Magnification × 500.

of the spore and expanded into a crescentic or rectangular projection darker in colour than the remainder of the spore coat.

Mean dimensions of thirty measured specimens: total length, 34μ (limits 26μ–44μ); maximum breadth of unthickened part of body, 21μ (limits 15μ–28μ); thickened projection, length 10 μ (limits 5μ–18μ); breadth 24μ (limits 16μ–35μ).

Thinner areas of the exine punctate with a finely notched margin, thickened projection smooth or indeterminately marked.

The spore has been observed in an immature condition in adherent masses. In such cases the terminal thickening is much less apparent and is represented by a narrow crescentic bulge. It is probable therefore that most of the thickening took place after separation from the tetrad.

T. securis can be recognized in thin sections of coal, and the hollow body cavity does not extend into the terminal thickening.

Discussion and Occurrence.

The structure of *T. securis* is most unusual ; it differs considerably from any previously described species. It is abundant in bands of micro-fragmental coal from the Big Vein seam at Norton Hill Colliery, Somerset, and has also been found in fairly large numbers in coals from Nantgarw Colliery, South Wales, and Manton Colliery, Nottinghamshire. It has not been seen in any coals from below the base of the Westphalian C.

ACKNOWLEDGMENTS

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Malvern Tectonics—A Contribution

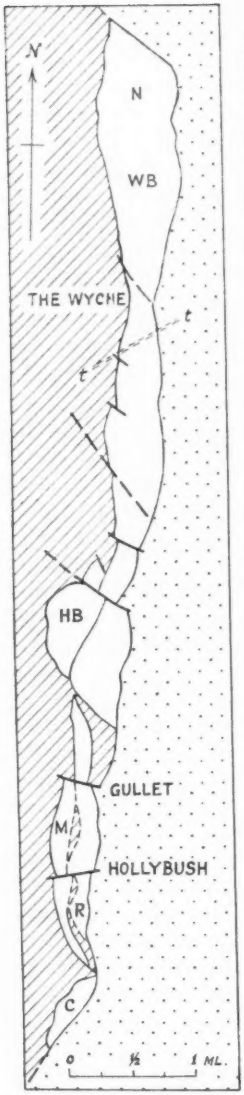
By F. G. H. Blyth

Abstract

The Malvern ridge consists of a series of Pre-Cambrian fault-blocks, which have been thrust upwards into their present positions through an overlying cover of Cambrian, Silurian, and Lower Old Red Sandstone sediments. The formation of the narrow, localized belt of folds which lie immediately to the west of the Malverns is the result of the displacement of the Pre-Cambrian basement blocks.

THE Malvern Hills, which lie on the borders of Herefordshire and Worcestershire, constitute a Pre-Cambrian ridge which rises to a series of distinct summits, extending from Chase End Hill in the south to North Hill (1,307 feet) in the north (Text-fig. 1). The structure of the Pre-Cambrian rocks and of the belt of folded Palaeozoic strata to the west of the ridge was described by T. T. Groom in a series of papers (1899, 1900, 1901, 1902, 1910), in which also he referred to the views of many earlier workers in the area. Of the published contributions to the study of the Malverns since 1910 the following may be noted : in 1926 T. Robertson recorded the sequence of formations found in the new Colwall railway tunnel ; the basic intrusions in the Cambrian inlier at the southern end of the Hills were re-described by Blyth (1935), who gave a map of the inlier and of the Pre-Cambrian ridge-blocks adjacent to it on the east ; a summary account of the area was given in " The Welsh Borderland " (Pocock and Whitehead, 1936) ; and, in a brief note, A. Brammall (1940) described some of the detailed structures within the Pre-Cambrian. More recently, N. L. Falcon (1947) and W. Mykura (1951) have discussed certain aspects of the tectonic history of the Malverns, especially the age of the structures.

Since the publication of Groom's extensive researches, the Pre-Cambrian ridge has generally been considered to be bounded by two north–south lines of faulting : (i) the Malvern Fault on the east, which brings Keuper Marl against Pre-Cambrian, and is held to continue for considerable distances to the north and south of the actual Malvern area. Groom stated that this was a normal fault with easterly hade and a maximum throw of 1,000 feet (1910, p. 717), the throw diminishing to some 200 feet in the south. The easterly hade was confirmed by observations in the railway tunnel (Robertson, *loc. cit.*) ; (ii) a more sinuous fault line on the west, regarded by Groom as an over thrust along which the Pre-Cambrian had been moved westwards over upturned, and in places, inverted, Palaeozoic strata. The folding and thrusting were thought to have taken place during the



TEXT-FIG. 1.—The Malvern Hills. Pre-Cambrian fault-blocks unshaded; Older Palaeozoic, lined; Trias, dotted. N, North Hill; WB, Worcester Beacon; *tt*, Colwall tunnel; HB, Hereford Beacon; M, Midsummer Hill; R., Ragged Stone Hill; C, Chase End Hill.

Hercynian movements, in late Carboniferous (Stephanian) times (Groom, 1910, p. 733).

Falcon (1947) has, however, suggested that the eastern side of the Malverns is a Triassic unconformity and not a major post-Triassic fault, though minor faulting was recognized. And in discussing the age of the folding of the Palaeozoic rocks to the west of the Malvern ridge, he has questioned Groom's evidence on which the dating of the movements was based. This evidence was concerned with the overturning of Coal Measures adjacent to the Abberley Hills (some 11 miles north of the Malverns, and close to the continuation of the Malvern line or "axis"). Falcon argued that the folding and over turning had affected formations up to and including the Lower Old Red Sandstone, but not the Upper Coal Measures: the movements thus took place during the interval between the deposition of the Lower Old Red and the beginning of the deposition of the Upper Coal Measures, and might be of an age ranging from Middle Old Red to pre-Upper Coal Measures.

This view has been questioned by Mykura (1951), who has re-examined the critical area at the southern end of the Forest of Wyre, and has come to the conclusion that, in the Abberley Hills, Coal Measures are in fact involved in the overturning, which he dates as of late- or post-Morganian age. He thus reverts, broadly, to Groom's original view, though his section across the Abberley Hills (*loc. cit.*, p. 388) does not show a recumbent syncline such as Groom portrayed (1900, p. 174).

The present paper seeks to set out a number of considerations, with particular reference to the southern part of the Malvern area, which affect the issues outlined above.

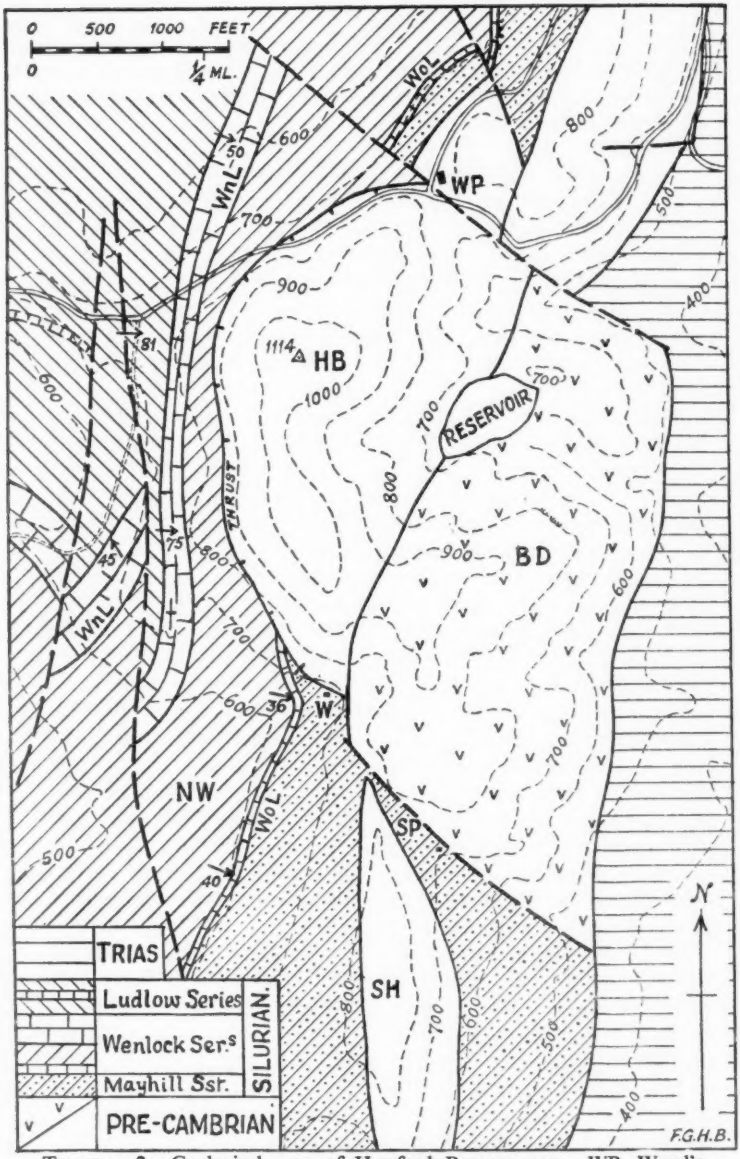
Faults Bounding the Pre-Cambrian

The Pre-Cambrian ridge of the Malverns is probably best described as a series of staggered fault-blocks. The blocks are bounded not by two continuous lines of faulting, but by a series of parallel or sub-parallel fractures which follow the general north–south trend of the ridge, and by transverse fractures (Text-fig. 1). This conception was suggested by Brammall (1940, p. 61) and was supported by evidence derived from his detailed study of the internal structures within the Pre-Cambrian.

Many of the transverse fractures have a north-westerly direction, though others are nearly east–west or east-north-east. They are well seen, for example, in that part of the ridge which lies between Hereford Beacon and the Wyche ; a map of part of this area was given by Robertson (*loc. cit.*). As the north-westerly fractures here (and elsewhere) cut and displace the nearly vertical Palaeozoics as well as the Pre-Cambrian, they were evidently formed late in the sequence of structures affecting the rocks, and are tear faults. Another north-west fault, terminating the Pre-Cambrian outcrop at North Hill, is shown on the 1-inch geological map (Old Series sheet 55 SE), though this line was replaced on Groom's map (1900) by a more sinuous boundary.

The more nearly north–south fractures which bound the Pre-Cambrian blocks appear generally to have an eastward dip, in some cases at a high angle, in others at a comparatively low angle so that they become thrusts. Thus, in the Colwall tunnel section the eastern fault, which brings Keuper Marl against Pre-Cambrian, dips east at 45 degrees, and the western fault (between Palaeozoics and Pre-Cambrian) is inclined at a somewhat higher angle (Robertson, fig. 18). This is one of the few localities from which evidence of the attitude of the faults below ground-level is available.

As illustrating the relationship between faults and thrusts the Hereford Beacon area may be selected : it is shown in Text-fig. 2, which is based upon 6-inch mapping by the writer, and is an area that has been worked over many times in the past score of years. Here, the western boundary of the Pre-Cambrian from near Wynd's Point to Walm's Well indicates the outcrop of a thrust plane, as noted by Groom (1900, p. 142, and fig. 3). The present writer's estimate of the dip of this thrust at its outcrop is 16 or 18 degrees to the east, or east by south. The Pre-Cambrian thrust-block overrides inverted Woolhope Limestone near Walm's Well, and at its western margin rests on vertical or inverted Wenlock Shales close to the Wenlock Limestone. It is



TEXT-FIG. 2.—Geological map of Hereford Beacon area. WP, Wynd's Point; HB, Hereford Beacon; BD, Broad Down; W, Walm's Well; NW, New's Wood; SP, Silurian Pass (of Groom); SH, Swinyard Hill; WnL, Wenlock Limestone; WoL, Woolhope Limestone.

bounded by a well-marked tear fault at Wynd's Point which trends nearly north-west. The Broad Down volcanic rocks (Warren House Series) immediately to the east of Hereford Beacon may constitute another thrust-block, or the volcanic series may lie unconformably on the Malvernian gneisses of the Beacon. The mapped boundary between the two masses appears to be a surface dipping east at about 60 degrees ; this junction is shown too steep on Groom's section (1900, fig. 3). The Broad Down block is bounded on the south by another north-west tear fault. Its eastern boundary may be a fault (against Keuper Marl) as Groom supposed ; or, if Falcon's suggestion of a Triassic unconformity is correct, it may be a fault partly concealed by a cover of Keuper Marl.

At Chase End Hill, the most southerly of the Malvern fault-blocks, the Pre-Cambrian is thrust over upturned Cambrian formations with their intrusive sills (Groom, 1899, fig. 16 ; Blyth, 1935, fig. 1). This thrust, at the present level of topography, is estimated by the writer to dip at about 27 degrees to the south-east, but may become somewhat steeper at depth. If it maintained a constant dip it would, in Groom's section, meet the eastern fault at shallow depth ; the Pre-Cambrian rocks of Chase End Hill would then form an isolated, rootless wedge. Structures in the rocks themselves, as seen in old quarries on the hill, include several small thrusts dipping between 20 and 30 degrees south-east.[1]

There is thus evidence, in at least the southern half of the Malvern range, that several of the Pre-Cambrian masses are in the nature of thrust-blocks, bounded laterally by north-west tear fractures ; the complementary set of tears, less well developed, probably trends east and west, or east-north-east, as at the Gullet and Hollybush fault-gaps through the Hills. The principal compression which brought about such thrusting would be approximately east-south-east and west-north-west ; though at Chase End Hill it would appear to have been more nearly north-west and south-east.

It is possible that the inclinations of the thrust planes change with depth below the surface. In a recent paper W. Hafner (1951) has discussed the attitude of fault surfaces in relation to stresses caused by tectonic deformation. He shows that, for certain conditions involving horizontal compression, a set of thrusts may be formed whose inclination increases with depth below the surface, though the complementary set is slightly concave upwards (i.e. flatter at depth), and is more commonly observed. In the Malverns we may have an example of the former, i.e. a group of thrusts which become somewhat steeper

[1] It is of considerable interest that thrusts striking N.E.–S.W. have also been recorded from the Woolhope area, some 10 miles west of Chase End Hill (R. W. Pocock, *Q.J.G.S.*, 1930, p. 58).

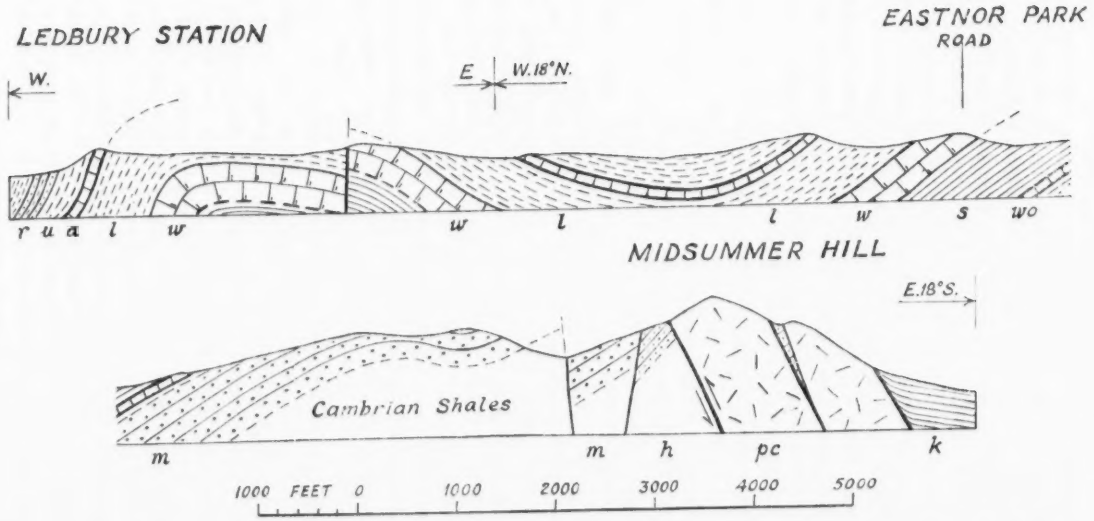
with depth below the surface. The Pre-Cambrian thrust- or fault-blocks must, in any event, represent parts of the basement which have been brought to the (present) surface from beneath a cover of Palaeozoic sediments by movements along inclined surfaces of fracture.

Folding in the Palaeozoic Rocks adjoining the Malvern Hills on the West

The north–south trend of the folds in the Palaeozoic rocks which lie immediately to the west of the Malvern ridge (referred to below as the Malvern belt of folds) is in sharp contrast to the east–west trend of the Armorican structures of the Mendips, only 50 miles to the south. Wells and Kirkaldy (1948, p. 168) consider that " it is inconceivable that the two grains—Armorican and Malvernoid—were developed at the same time : presumably the latter is slightly older than the former ". In discussing this matter it is important to note that the Malvern belt of folds has a very limited width. The zone of disturbance is long and narrow ; between Ledbury and the Hills it reaches a maximum width of some three miles, but to the north it is much narrower. The Lower Old Red Sandstone is involved in the folding together with the Older Palaeozoics. West of Ledbury, and in the adjoining country to the north, the Old Red forms an extensive outcrop and is only gently folded. But in the neighbourhood of Ledbury Station the beds suddenly acquire a dip of 74 degrees or more to the west, and form the steep westerly limb of the Ledbury anticline. Other folds follow to the east until they are truncated by the faults bounding the Pre-Cambrian (Text-fig. 3). A little to the north of the line shown in this section the Palaeozoic rocks have been upturned into the vertical position, or even overturned, where they abut against the Pre-Cambrian as already described.

Direct evidence of folding in the Palaeozoic rocks to the *east* of the Malvern fault is lacking, as the older rocks are here concealed beneath gently dipping or horizontal Triassic formations. They lie at considerable depths, as is shown by bore-hole records : thus the boring at the Malvern Links Gas Works penetrated 950 feet of Keuper Marls and Sandstones without reaching the Palaeozoic floor ; and at Upton-on-Severn (6 miles east of the Hills) a boring for water was sunk 1,700 feet and was still in Triassic sediments. Further afield, bore-holes at Batsford and Calvert (about 28 and 60 miles E. by S. of Great Malvern) penetrated Silurian rocks at a depth of 1,546 feet, and Cambrian at 444 feet respectively. Such records appear to indicate that the Palaeozoic floor drops sharply on the east side of the Malverns,[1] as would be expected if a large fault were

[1] This is borne out by the gravity survey profile recently recorded by Falcon and Tarrant (*Q.J.G.S.*, 1951, plate xi).



TEXT-FIG. 3.—Section from Ledbury Station to Midsummer Hill. *r* = Lower Old Red Sandstone ; *u* = Upper Ludlow ; *a* = Aymestry Limestone ; *l* = Lower Ludlow ; *w* = Wenlock Limestone ; *s* = Wenlock Shales ; *wo* = Woolhope Limestone ; *m* = Mayhill Sandstone ; *h* = Hollybush Sandstone ; *pc* = Pre-Cambrian ; *k* = Keuper. Vertical scale = $1\frac{1}{2}\times$ horizontal.

crossed. The fact that the Palaeozoic rocks are brought to the surface west of the Malverns and, in the writer's opinion, the available field evidence, go to show that the belt of folding there is only a local one, and that it is related primarily to the Malvern fault line.

The view is advanced, therefore, that the Malvern belt of folds is not the result of a regional folding on a large scale, because only a narrow belt of ground is demonstrably affected, but that it is probably related in origin to movement on the system of faults which bound the Pre-Cambrian ridge. In the early literature the folds tended to acquire a regional status, partly perhaps because of Groom's deduction that complex folding had affected both the Pre-Cambrian and the overlying rocks together. Thus, Cambrian and Silurian sediments were thought to be infolded within the Pre-Cambrian in enormous isoclinal structures (see, for example, Groom, 1899, figs. 18 and 19). These "infolds" become, on the present interpretation, fault-slices or wedges let down or caught up into the Pre-Cambrian during the fault movements. This appears to the writer to be a simpler mechanism to account for the presence of the sediments, and is also in accord with the types of structure present in the Pre-Cambrian rocks themselves, as seen clearly in a number of large quarry exposures. At the Hollybush and Gullet road-metal quarries, for instance, the metamorphic and igneous rocks of the Pre-Cambrian are traversed by innumerable thrusts, faults, and shear zones; structures due to fracturing are pre-eminent, and the fractures forming one dominant set are the thrusts which rise to the north-west or west-north-west.

The above interpretation is further supported by a consideration of the amount of horizontal shortening involved in the Malvern folds. If the original (unfolded) extent of the Palaeozoic strata along an east–west line from Ledbury to the Hills (Text-fig. 3) is estimated and compared with their present extent, a horizontal shortening of about 12½ per cent is indicated, or nearly 2,000 feet in the tract 3 miles wide. Although this estimate may not be of the highest accuracy, it does at least give some idea of the order of magnitude of the effects involved. Horizontal shortening of this amount could have been produced by the upthrusting movements of the Pre-Cambrian basement below its cover of Palaeozoic sediments, the latter being dragged and ridged up into their present positions by movements on the faults.

It is perhaps significant for comparison with the figures above that the Hereford Beacon mass lies some ¼ mile west of the line of hill summits from Swinyard Hill southward, and (as mentioned by Bennett, 1942) about ½ mile west of the line of the hills to the north. The broadest exposed part of the belt of Palaeozoic rocks is thus adjacent to those thrust blocks which have travelled farthest west.

Evolution of the Fracture System

It is, unfortunately, a difficult matter to decide the orientation and sense of the movements which gave rise to the fracturing in the Pre-Cambrian basement. The structures in the thrust-blocks are complex, and may not all have been formed at one time. From the evidence of the southern part of the Malverns area, an E.S.E.–W.N.W. compression of late Caledonian (Middle Old Red Sandstone) age would probably account for the folding and overthrusting. In the Abberley Hills, however, Coal Measures appear to be involved in the folding (Groom, 1910 ; Mykura, 1951), though this has been disputed (Falcon, 1947), and this would invoke an early Armorican episode. Probably more than one period of movement has been involved in the evolution of the Malvern structures ; the initiation of the fracture pattern in the basement rocks may, indeed, date back beyond Palaeozoic time to a still earlier epoch.

Whether the main part of the Malvern structures came into existence during a late stage in the Caledonian orogeny or in an early phase of the Armorican, in either event they would be subject to possible modification during the later Armorican stages and also during the Alpine movements (which produced important folds in Dorset, 100 miles to the south). It is known from the Colwall tunnel records, as already related, that the Keuper Marl is there faulted against Pre-Cambrian rocks in the eastern part of the tunnel ; the fault surface dips 45 degrees east, and the Keuper beds are turned up parallel to it. An approximately north–south compression, acting on the earlier faults which trend roughly north and south and bound the Pre-Cambrian ridge, would tend to open them after the manner of tension fractures, and slipping on these faults may then have taken place, thus giving rise to normal faulting with downthrow to the east. This would account for the attitude of the Keuper seen in the tunnel and for similar downthrows probably occurring elsewhere along the Malvern line. A Tertiary age for these late movements may be presumed.

Summary

The Malvern ridge consists of a series of Pre-Cambrian fault-blocks bounded by fractures, among which thrusts dipping east or east-south-east, and north-westerly tears, are prominent. The fault-blocks were elevated by movements affecting the Pre-Cambrian basement, on which a considerable thickness of Palaeozoic sediments (Cambrian, Silurian, and Lower Old Red Sandstone) had been deposited. These sediments were folded and fractured along a narrow north–south belt by the displacement of the underlying Pre-Cambrian blocks : upward movement on easterly dipping surfaces involved a

westward horizontal component of movement. The folds in the Silurian thus have steep western limbs, as can be seen at Ledbury ; the strata are also vertical or inverted near the Pre-Cambrian masses, and are traversed by many faults. In at least two places (Hereford Beacon and Chase End Hill) Pre-Cambrian masses have been driven forward on thrust planes in a west-north-west or north-west direction.

The date of the main movements lies between late Caledonian and Armorican ; an E.S.E.–W.N.W. compression of Middle Old Red Sandstone age would account for the evidence in the southern Malverns, but late Carboniferous movements may also have affected the area. Adjustments on the main faults probably occurred during a north–south compression of early Tertiary age ; but this was a minor matter in comparison with the movements which elevated the Pre-Cambrian horsts.

In conclusion the writer wishes to express his thanks to Dr. A. Brammall, Professor V. C. Illing, F.R.S., and other colleagues for many past discussions concerning the Malvern structures.

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The Origin of the Supposed Tufa Bands in Carboniferous Reef Limestones

(PLATE VI)

By W. W. Black

Abstract.

Thin bands of fibrous calcite occur in the Carboniferous reef limestones of northern England and have been regarded as bands of primary tufa within a marine limestone series. A study of these fibrous bands has been carried out and the results show conclusively that they are in fact secondary recrystallization structures.

Introduction

THE literature on Carboniferous reef limestones contains many references to thin bands of fibrous calcite, often called " reef-tufa ", which occur within the limestones. Tiddeman appears to have been the first to comment on these structures and their interpretation as tufa is due to him. In the course of a public lecture to the Craven Naturalists in 1892 he is reported as saying " . . . in many places the limestone, when it is made chiefly of fine fragments or grains of fossils, is full of little floors of stalagmite or tufa running more or less horizontally through the mass ". He went on to suggest that sea-spray or rain water dissolved lime from calcareous sand lying above water-level and then, on drying, gave it up again (see Kendall and Wroot, 1924, p. 95). I can find no further elaboration of this interpretation by Tiddeman nor does the matter appear to have been discussed critically by later workers (e.g. Parkinson, 1950, and Bond, 1950), most of whom have accepted the fibrous bands as examples of fossil tufa in a marine limestone. J. E. Prentice, however, does not subscribe to this view since he states " . . . there can be little doubt that it (the banding) represents, in recrystallized state, the layered skeletons of the reef-forming calcareous algae " (1951, p. 179).

During a petrographic examination of certain reef limestones at Whitewell, in Bowland, I sectioned a number of fibrous bands and came to the conclusion that they represented the local recrystallization of the calcite mudstone which is the dominant rock type. Additional thin sections, including samples from the Cracoe reef belt and from Derbyshire and Staffordshire, have amply confirmed this conclusion, the evidence for which is set out below.

Distribution of the Fibrous Bands

The fibrous bands are irregularly distributed in the reefs, being common in some and quite rare in others (see, for instance, Parkinson,

1950, p. 273). They may also be largely restricted to certain stratigraphical horizons as described by Bond at Cracoe. It is my experience that the bands are confined to the very fine-grained limestones such as calcite mudstones and their slightly recrystallized varieties. The presence of this particular lithology does not, however, mean that the bands will necessarily be present. Where occasional fibrous bands occur in an apparently clastic (i.e. grain or fragmental) limestone it will usually be found that they are, in fact, associated with thin layers of calcite mudstone (see, for instance, Bond, 1950, p. 167). The fibrous bands are sometimes rather inconspicuous except on well weathered surfaces and, since the rock breaks most readily along the bands, it is easy to attribute to the whole rock the texture of the fibrous calcite as seen on a freshly broken surface. This is a texture best described as " sugary ".

Macroscopic Characters

As seen in hand specimens, the simpler fibrous bands are a few inches in length and of the order of a quarter of an inch in depth. They obviously represent sections of very flat ovoid structures. The upper and lower margins of the bands are usually slightly irregular and often markedly so, but, however irregular these margins might be, the fibrous crystals, easily seen on a weathered surface, are always at right angles to that part of the margin with which they are in contact. Bedding planes are often ill-defined or absent in the reef limestones but, when they are to be found, the fibrous bands lie approximately parallel to them.

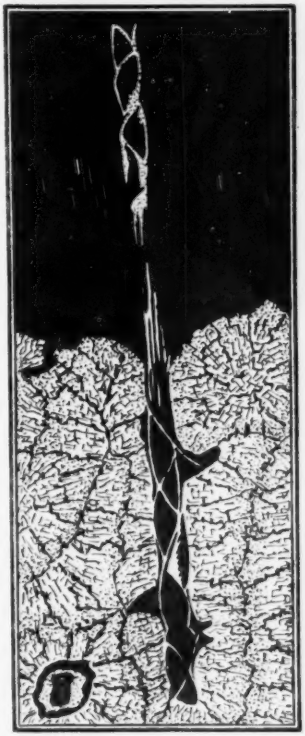
The fibrous bands are frequently more complex than the simple type first described. They may appear to be gently undulating or even have the appearance of violent contortion (see, for instance, Parkinson, 1950, p. 273). Two or more simple bands may merge laterally to form a single complex band. This complex band may contain several distinct fibrous layers, those near the centre often being roughly circular and often enclosing a fossil. In other cases bands lying one above the other may be joined by a vertical band. There is frequently a rapid alternation of fibrous bands with limestone, the alternate layers being an inch or less in thickness.

It has already been remarked that bedding is poorly developed in these limestones. This can only mean that pauses in sedimentation were rare and short-lived. The formation of tufa in a marine series would involve extensive uplifts with the consequent development of tufa-covered bedding planes or erosion surfaces. Certainly, the fibrous bands are not associated with such surfaces and this, together with the interdigitation of limestone and fibrous bands and the existence

of vertical connecting bands, constitutes strong evidence of a secondary rather than a primary origin for the fibrous calcite.

Microscopic Characters

In thin sections the relationship of the bands to the surrounding limestone can be clearly seen. The limestone itself, in the specimens from Whitewell, is a grey or buff-coloured calcite mudstone, only slightly translucent, in which little or no structure can be seen. It contains variable, usually small, amounts of calcareous organic remains, these being usually bryozoans and very small crinoid ossicles. Less commonly, entire gastropod and brachiopod shells occur and small, presumably immature, examples are to be seen in thin sections. Small crystals of euhedral quartz with highly birefringent inclusions are usually present, occasionally in such abundance as to make up 20 per cent of the rock. These crystals are disseminated throughout the rock and are regarded as authigenic. Pyrite is invariably present.

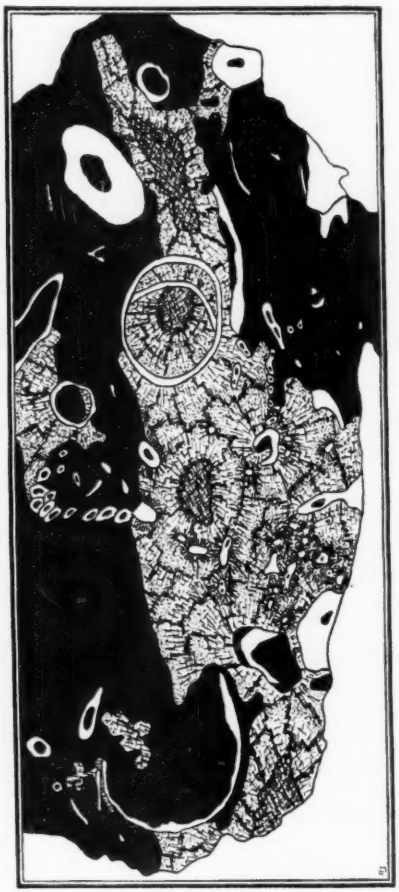


Text-fig. 1.—A bryozoan stipe located half in a fibrous band and half in the overlying calcite mudstone (solid black). Whitewell, Bowland. × 28.

The boundary between limestone and fibrous bands is always very irregular along the upper surface of the band, the fibrous calcite penetrating into the calcite mudstone in elongated salients. The actual contact between the two is always very sharp, though there may be a narrow intermediate zone consisting of minute " clots " of calcite mudstone in a slightly more crystalline matrix.

The simpler fibrous bands are seen to consist of roughly parallel calcite crystals elongated normal to the margins of the bands and often in two rows, an outer one of small crystals and an inner one of larger crystals, each persisting completely around the band. This demonstrates that crystal growth took place outwards from the central part of the

band and not upwards from the base. In addition there may be a central zone of crystals with an indiscriminate orientation. Quartz is often present, but its form is quite different from that of the small crystals of euhedral quartz scattered throughout the adjacent limestone. It occurs



TEXT-FIG. 2.—Drawing of a fibrous band and associated calcite mudstone (solid black) showing fossils distributed throughout both and often located partly in one and partly in the other. Note, also, residual patches of calcite mudstone within the fibrous calcite. "Tufa" beds, Butterhaw, Cracoe. × 3.

in irregular crystals comparable in size with the larger calcite crystals with which it occasionally forms an intergrowth. Pyrite is invariably present, in small amounts. Where fossils are present in the associated limestone they are usually to be found in the fibrous bands also. In many cases they are located partly in the limestone and partly in the

fibrous calcite, this constituting the strongest single piece of evidence for the secondary nature of the bands (Text-figs. 1 and 2). The bryozoans are particularly instructive since they have often been partly replaced by fibrous calcite crystals which have their long axes normal to the margins of the bryozoan remnants. In these cases there can be no doubt that the fragments mark the position of the original entire stipe and that the missing portions have been recrystallized. This is important since it shows how a shell or a shell fragment may become surrounded by fibrous calcite, giving the misleading appearance of a fossil encrusted with tufa. Thus, crinoid ossicles and shells of brachiopods, gastropods, and lamellibranchs have proved resistant to the process which has recrystallized some or all of the surrounding calcite mudstone with the consequent partial or total enclosure of the fossils within the fibrous calcite.

Thin sections of the more complex fibrous bands show a very complicated arrangement of fibrous layers which is interpreted as being due to the differing resistance offered by various parts of the rock to the recrystallization process. Long salients of the recrystallizing calcite eating into the more easily affected rock have joined up with one another giving rise to double rows of fibrous crystals, often with a very thin film of calcite mudstone remaining between, while within the recrystallized zone other rows of fibrous crystals have developed around resistant fossils.

Summary of Evidence

The following features, among others, show that the fibrous bands are secondary structures due to local recrystallization of the calcite mudstone and are not bands of primary tufa :—

(1) Fossils may be located half in the fibrous calcite and half in the overlying limestone.

(2) Two or more horizontal bands may be connected by vertical fibrous bands.

(3) Bryozoans in the fibrous bands have usually been partly recrystallized.

(4) The same marine fossils are found in both the fibrous bands and in the surrounding limestones.

(5) The upper boundary of the bands is of the extremely irregular nature usually associated with recrystallization and replacement processes.

(6) The bands are not associated with bedding planes or other surfaces indicating a break in sedimentation. On the contrary, they alternate with, interdigitate with, and pass laterally into normal marine limestone.

There are no structures associated with the bands which could be interpreted as algal and the bands do not form a continuous network.

An explanation of the mechanism of this recrystallization will not be attempted here. It may be said, however, that the factors most probably involved are the production of CO_2 consequent on the biochemical breakdown of organic detritus and the peculiar conditions of sedimentation of the reef limestones themselves—particularly the relatively rapid rate of sedimentation and the sporadic distribution of organic remains.

I would like to record my thanks to my wife, to Professor W. D. Evans, and my colleagues in the Department of Geology for helpful discussion, and to Mr. R. Johnson who drew the text-figures.

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EXPLANATION OF PLATE VI

Photomicrograph of part of a fibrous band. Dark areas are calcite mudstone, residual patches of which are seen within the fibrous band, together with a crinoid ossicle and a shell fragment which forms the local boundary of the band. Whitewell, Bowland. Ordinary light. × 14.

RECRYSTALLIZATION STRUCTURES IN CALCITE MUDSTONE.

Allometric Growth in *Dielasma hastata* from Treak Cliff, Derbyshire

By Donald Parkinson

Abstract

Growth and variation in a single species from a thin bed at one locality are examined statistically. The different dimensions are shown to be allometrically related both to each other and to the volume of the shell. It is argued that total width is the best measure of age of the individual and it is shown that at a certain width there is a break in the continuity of growth of the length and thickness.

Introduction

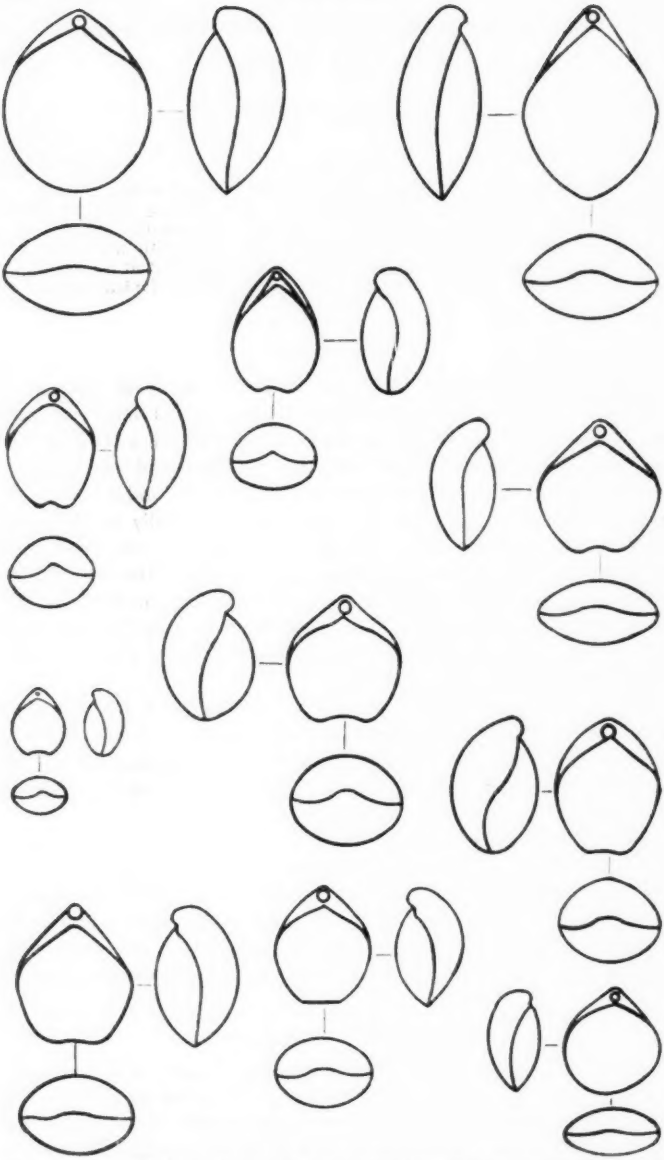
THE specimens of *Dielasma* on which this study is based were all collected from the Lower Carboniferous reef limestone of Treak Cliff, near Castleton, Derbyshire. Out of a total of 527 individuals which have been submitted to statistical examination, 475 were obtained from a pocket a few inches thick and a few feet in extent. They can therefore be regarded substantially as all living at the same time and place. The bed in question, which is situated immediately below the summit ridge near the top of the steep north-eastern dip slope, is rich in brachiopods, both in individuals and species, the commonest form being the one under consideration. The age of this bed (which will be referred to as the *Dielasma* bed) is considered to be high middle D_1.

The remaining fifty-two specimens were collected from various localities on Treak Cliff, all of them presumably higher in horizon than the *Dielasma* bed. Stratigraphical work now in progress aims at determining the details of the sequence in this small area and amplifying the results of previous work (1940, 1946).

The writer wishes to thank Mr. Trevor Ford and other students from Sheffield University for assistance in collecting from the *Dielasma* bed. On the statistical side he is glad to acknowledge helpful criticism from Mr. B. J. A. Martin and Mr. C. H. Leigh-Dugmore, and he is indebted to Mrs. P. E. Pritchard for valuable help in the computing. He has also to thank Mr. H. R. Willcocks for drawing the diagrams.

Preliminary Considerations

Although the specimens exhibit a moderate degree of variation in external form (Text-fig. 1), there seemed at the outset no valid reason for separating them into more than the one species *Dielasma hastata* (J. de C. Sowerby). They agree in general characters with the type in the British Museum (Natural History) collection (B61657). Some of



TEXT-FIG. 1.—*Dielasma hastata* from the *Dielasma* bed, Treak Cliff, illustrating variation in external form. All figures natural size.

the smaller individuals show some external resemblance to *Girtyella* ? *sacculus* (Martin), but the latter form has been shown by Dr. Muir-Wood (1951) to possess a median septum in the brachial valve and therefore not to belong to the genus *Dielasma*.

The interiors of the Treak Cliff specimens are filled with crystalline calcite, and little is known as yet of the internal structure. The dental lamellae in the pedicle valve are sometimes preserved. There is no evidence of a dorsal median septum in any of those specimens which show traces of structure when ground down from the umbo. The species seems to be a member of the genus *Dielasma* as interpreted by Weller (1914), the appearance in cross-section somewhat resembling Weller's diagrams of *D. chouteauensis* (p. 258) ; but more work is needed to establish fully the internal characters.

Although the possibility of homoeomorphy cannot be entirely excluded, it is thought to be a reasonable assumption that only one genus is represented. This applies in particular to the 475 specimens from the *Dielasma* bed.

Frequency Distributions

The distributions of the three dimensions, total length, width, and thickness, are illustrated by the histograms in Text-fig. 2 and call for no comment. Frequency polygons and histograms of the ratios of the different dimensions (Text-figs. 3 and 4) are consistent with the hypothesis that all the specimens can be referred to one species, since all the frequency distributions show only one well-defined peak. It is thought to be improbable that a frequency diagram of a mixed population from the same bed would be unimodal for all characters. On the other hand, a single species might display bimodal distributions. Such an instance has recently been recorded by Westoll (1951), who plotted frequency polygons of the Permian brachiopod *Dielasma elongata* (Schloth). Of four ratios he considered, three gave unimodal distributions and one—the thickness/total-length—gave bimodal distribution, the " thin-form " and " thick-form " shells above a certain size being about equal in number. This suggests, according to Westoll, sexual dimorphism.

There is no evidence of bimodality in the Lower Carboniferous *Dielasma*, and its difference from the Permian form is indicated in Text-fig. 3, the dotted lines in which are copied from Westoll's figure.

The values of the means, ranges, and standard deviations of (*a*) the sample of 475 individuals from the *Dielasma* bed and (*b*) the sample of fifty-two individuals from other localities on Treak Cliff are tabulated below. The data indicate that sample B, which is taken over a wider time interval than sample A has, as might be expected, a wider variation of characters.

		Dimensions in mm.		
		Length.	*Width.*	*Thickness.*
Means . . .	A	15·94	13·13	8·46
	B	14·28	11·52	7·95
Ranges . . .	A	7·2–45·5	5·6–33·2	3·3–23·8
	B	4·6–29·0	3·9–20·7	2·4–14·1
Standard deviations .	A	4·918	3·543	2·805
	B	5·382	4·012	2·829

		Ratio of Dimensions.		
		W/L.	*T/W.*	*T/L.*
Means . . .	A	·834	·636	·528
	B	·818	·696	·566
Ranges . . .	A	·625–1·000	·435–·913	·380–·721
	B	·638– ·956	·450–·966	·383–·754
Standard deviations .	A	·0644	·0868	·0618
	B	·0713	·1066	·0891

Differential Growth

(i) *General Considerations.*—Growth studies by the author on a number of species, representing several Lower Carboniferous brachiopod genera, have indicated in many cases that throughout a large part of the life of the organism, the size of a part y, of the shell is related to some standard, x, which may be the total length or width, by one or other of the equations

$$y = a + bx,$$
$$y = bx^{\alpha}$$

where a, b, and α are constants.

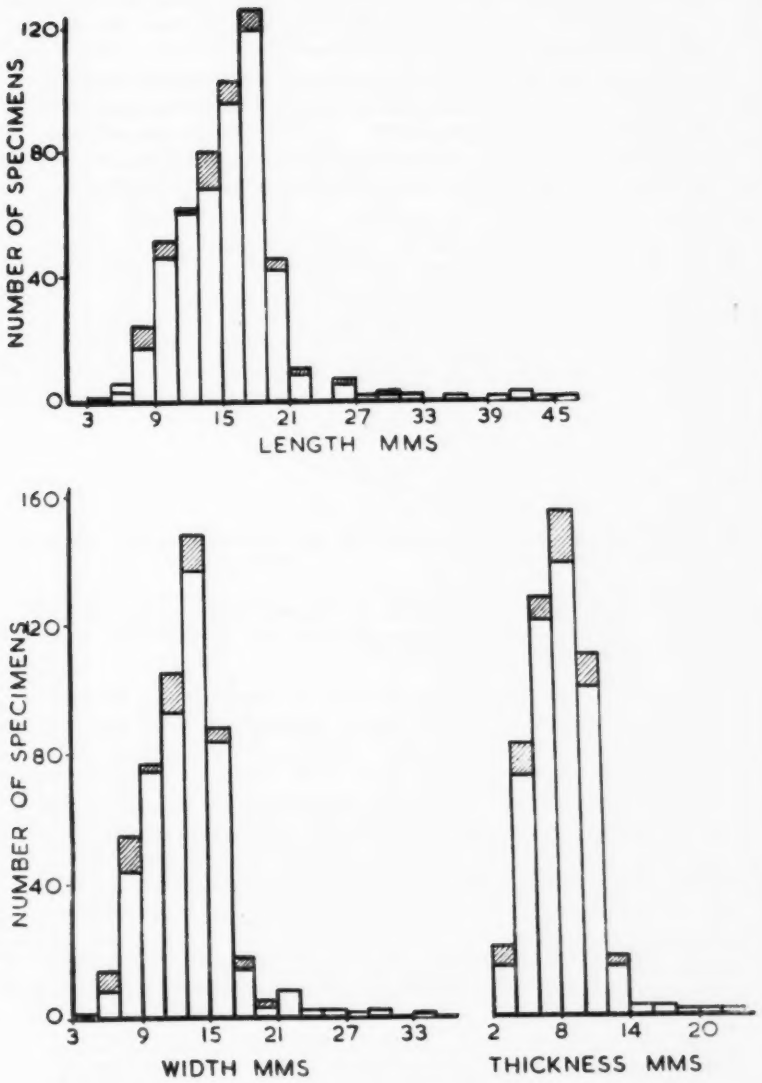
In the first equation, which expresses isometric growth, the geometric growth rates of x and y are equal, but the increments are unequal (b is not equal to 1) and the ratio, y/x, is not constant. The regression of y on x is rectilinear on a scatter diagram relating the two dimensions; and the regression coefficient, the average amount that y changes for a unit change of x, is an estimate of b.

The second formula is the well-known allometry equation and means that the geometric growth rates of x and y maintain a constant ratio, α. The ratio y/x is not constant and is equal to b when $x = 1$. The regression of y on x is curvilinear on arithmetical co-ordinates, but rectilinear for logarithmic co-ordinates, when the equation becomes

$$\log y = \log b + \alpha \log x$$

in which the regression coefficient is an estimate of α.

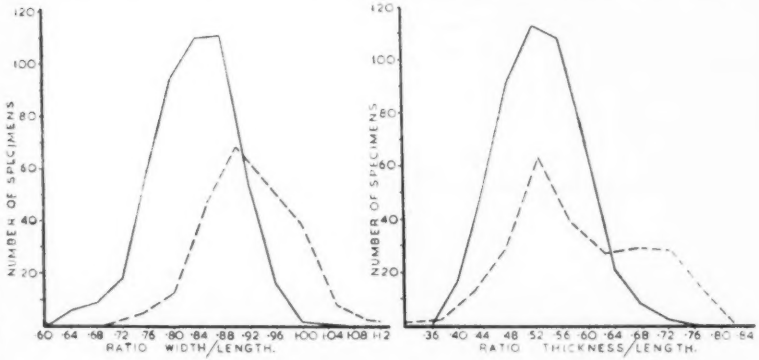
The regressions are approximately linear both on arithmetical and logarithmic co-ordinates when α differs little from 1 and a is not far removed from 0, and in such cases (which in the writer's experience



TEXT-FIG. 2.—Histograms of the three dimensions. The clear areas represent specimens from the *Dielasma* bed and the shaded areas from other beds on Treak Cliff.

are not uncommon), either formula can be used. When the scatter is more uniform on logarithmic plots, as is often the case, the allometric equation is to be preferred.

The allometric formula figured prominently in a discussion recently held on the measurement of growth and form under the leadership of Professor S. Zuckerman (1951). A point at issue was whether this equation, which in particular is associated with the name of Julian Huxley, has the status of a biological or physiological principle,



TEXT-FIG. 3.—Comparison of frequency polygons of the ratios of the dimensions of *Dielasma hastata* from the Carboniferous Limestone, Treak Cliff (full lines) and *Dielasma elongata* from the Magnesian Limestone (dotted lines, after Westoll).

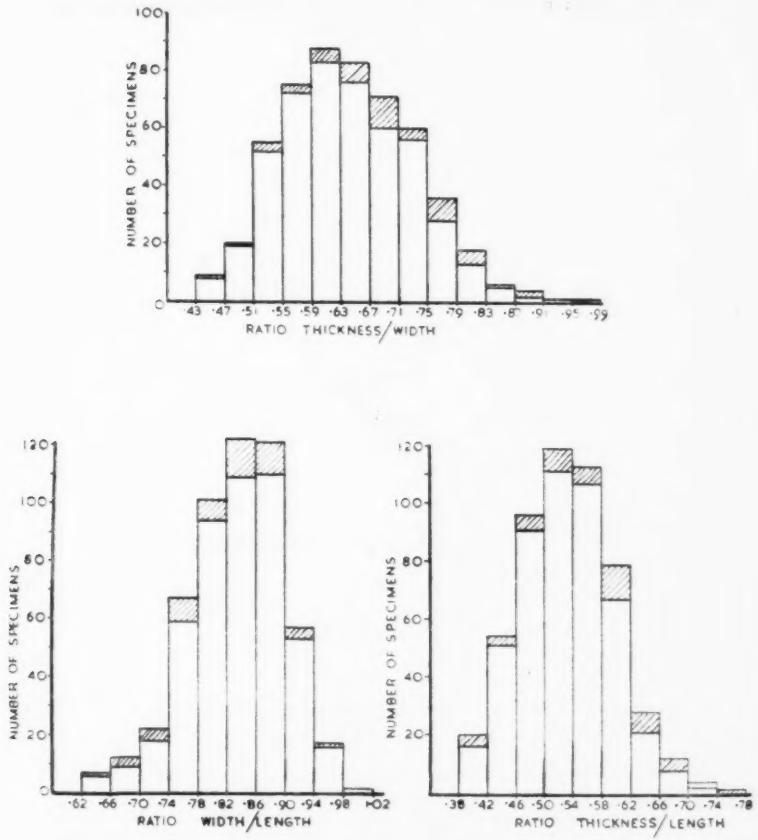
or should be regarded merely as an empirical description of the relation between the growth of two parts of an organism. This question arises because of the mathematical difficulty of reconciling an allometric relation of two different parts of the organism to the whole with one relating them to each other. Relative growth in fossil groups was discussed by Professor T. S. Westoll, who mentioned Newell's allometric studies in invertebrates and cited many instances in vertebrates where growth relations follow the simple allometric formula. It was emphasized that such growth studies could be of help in phylogenetic problems.

(ii) *Growth Features in Dielasma hastata.*—The Treak Cliff collection is a suitable one for a growth study in a fossil species, since it includes a wide range of sizes.

A scatter diagram relating length to width (not reproduced in this paper) indicated a curvilinear relationship, the ratio width/length decreasing with size.

Plots of the logarithms of the dimensions length-width, thickness-length, and thickness-width indicated linear regressions and the

applicability of the simple allometry equation in each case (Text-figs. 5, 6, and 7). In these three diagrams the specimens from the *Dielasma* bed are represented by dots and those from the other exposures by

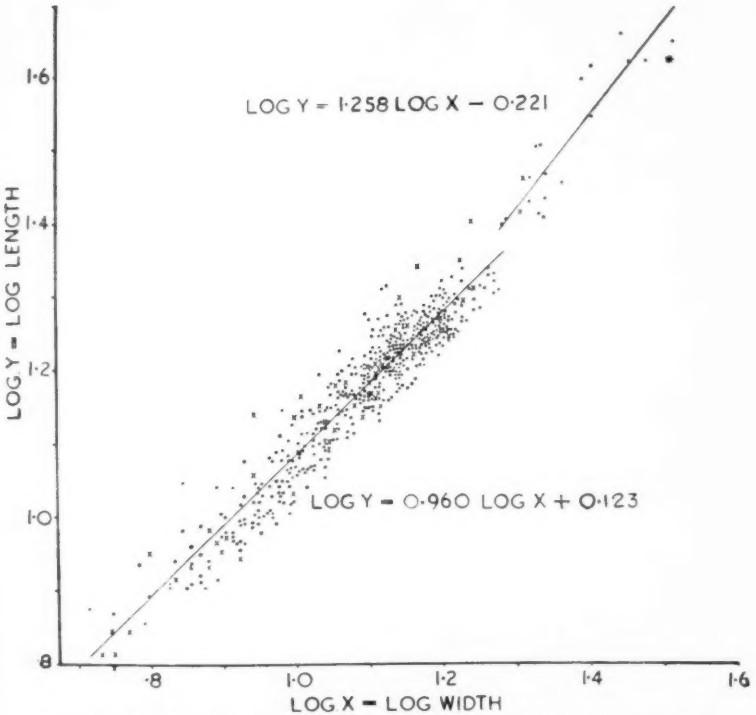


TEXT-FIG. 4.—Histograms of the ratios of dimensions. The clear areas represent specimens from the *Dielasma* bed and the shaded areas from other beds on Treak Cliff.

crosses. The holotype (from the Carboniferous Limestone of Limerick) is denoted by an asterisk. The regression lines take account only of the 475 specimens from the *Dielasma* bed. As drawn they indicate a break in the continuity of growth at a certain size, or alternatively

that the eighteen larger specimens belong to a different species from the 457 smaller ones.

In considering these alternatives it is necessary to discuss the reasoning which led to the choice of the independent variable, since two regression lines can be drawn through a scatter diagram and the

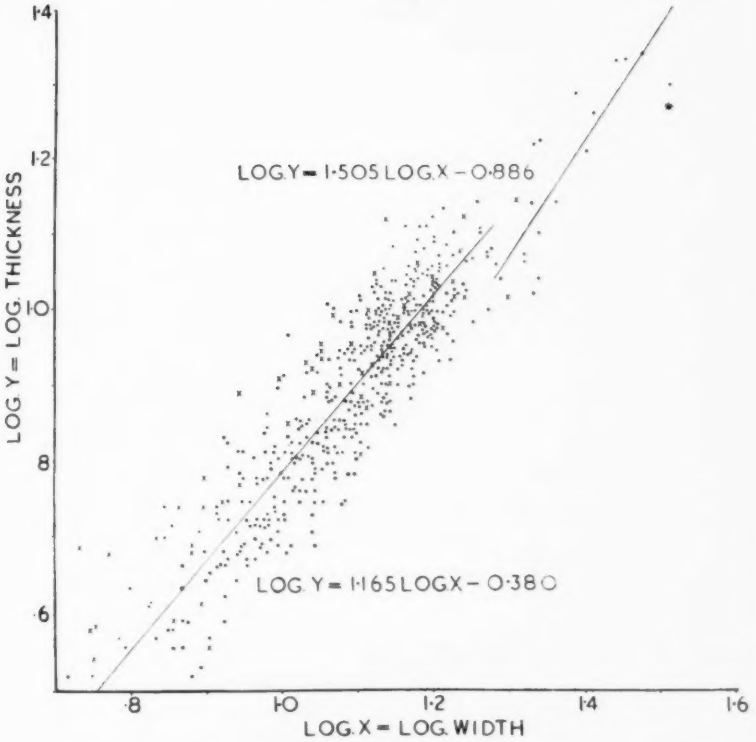


TEXT-FIG. 5.—Relationship between log length and log width. The regression lines are based on the specimens, represented by dots, from the *Dielasma* bed only. The crosses comprise specimens from other localities on Treak Cliff, and the asterisk represents the holotype from the Carboniferous Limestone of Limerick.

regression of y on x will only be equal to the regression of x on y in the rare instance when all the points lie on one line and are not scattered about it.

The independent variable should be the character most nearly representative of age (of the individual). This seemed to rule out the thickness, since it is a matter of observation that the thickness or

globosity of brachiopod shells is more variable than either the length or the breadth. But a more rigorous approach was sought, particularly as in the case of the length-width diagram the choice appeared to be arbitrary. Because of the suggestion of breaks in the scatter diagrams it was thought that further light would be thrown on the

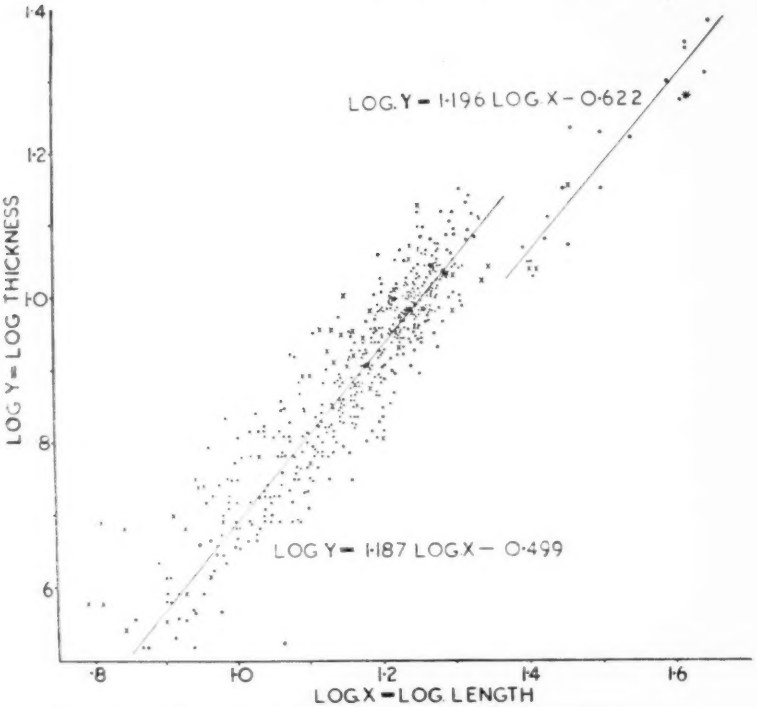


TEXT-FIG. 6.—Relationship between log width and log thickness. (Other particulars as in Text-fig. 5.)

problem if each dimension could be related separately to the total volume of the shell. In Text-fig. 8 the logarithms of each dimension of the specimens from the *Dielasma* bed are plotted against the logarithm of the product of length × width × thickness which, because of the symmetry of the shell, can be regarded as proportional to its volume. It is seen that in the case of both length and thickness the eighteen points representing the largest specimens are markedly

displaced from the narrow band containing the other 457 specimens, but there is no such displacement in the case of the scatter of width.

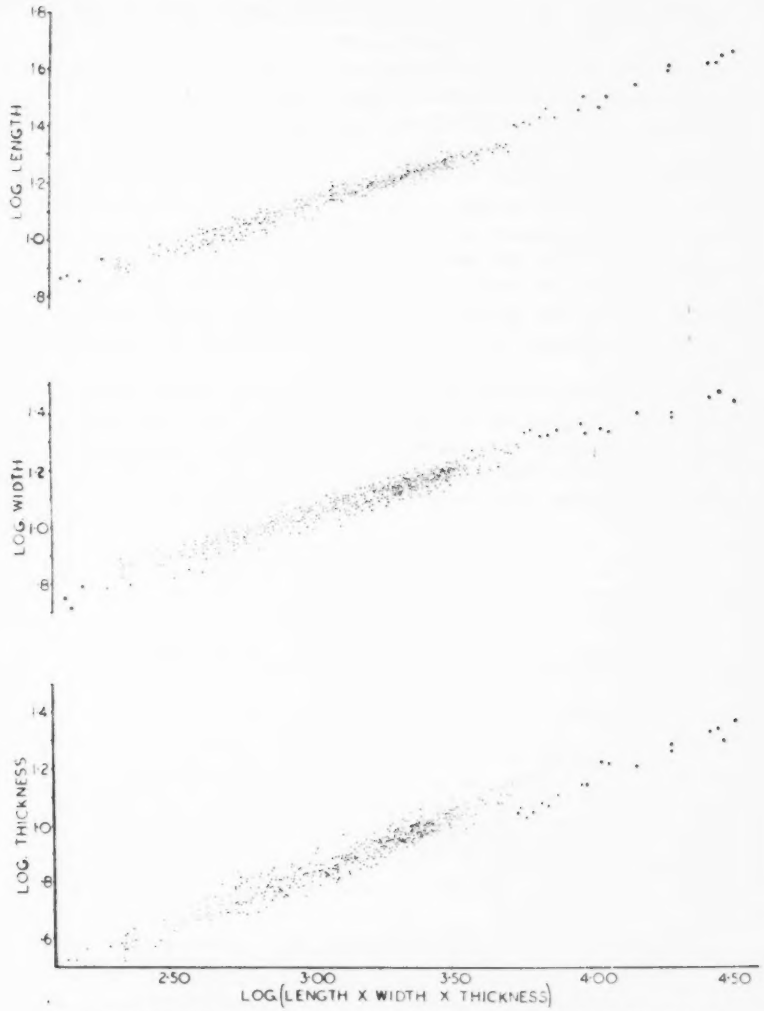
The absence of any displacement or change in the trend of the width-relative volume scatter suggests that the breaks in the diagrams are functions of growth change in a single species, and not a consequence



TEXT-FIG. 7.—Relationship between log length and log thickness. (Other particulars as in Text-fig. 5.)

of the mixed sampling of two populations. Furthermore, there is no suggestion of overlapping of the two sets of points in the length-relative volume and thickness-relative volume diagrams, as might be expected if two species were represented.

The combined evidence, therefore, from the examination of external and internal characters, from the frequency polygons and histograms and from the scatter diagrams, is consistent with the view that all the specimens (certainly all those from the *Dielasma* bed) should be referred to a single species.



TEXT-FIG. 8.—Relationship between the logarithms of the three dimensions and the logarithms of the relative volume of the shell (log L × W × T) of specimens from the *Dielasma* bed.

The three diagrams of Text-fig. 8 indicate that the dimension most representative of age is the width. Throughout growth the relationship between log width and log relative volume is apparently unchanged,

and it is evident that the log width should be taken as the independent variable in the regression equations relating it to log length and log thickness. In the log length-log thickness equation the former is chosen as the independent variable for a reason which is advanced later.

The facts illustrated by Text-fig. 8 are explicable on the view that, at an age represented by a width of about 19 mm. there was a sudden and temporary increase in growth rate of the length corresponding to a temporary halt in thickness growth. At the same time the width continued to increase at the normal rate. But since the number of available specimens that reached this particular condition is small the possibility that the phenomena can be accounted for by random variation should not be excluded, and it is necessary to apply statistical tests of significance to the data by comparison of the regression coefficients.

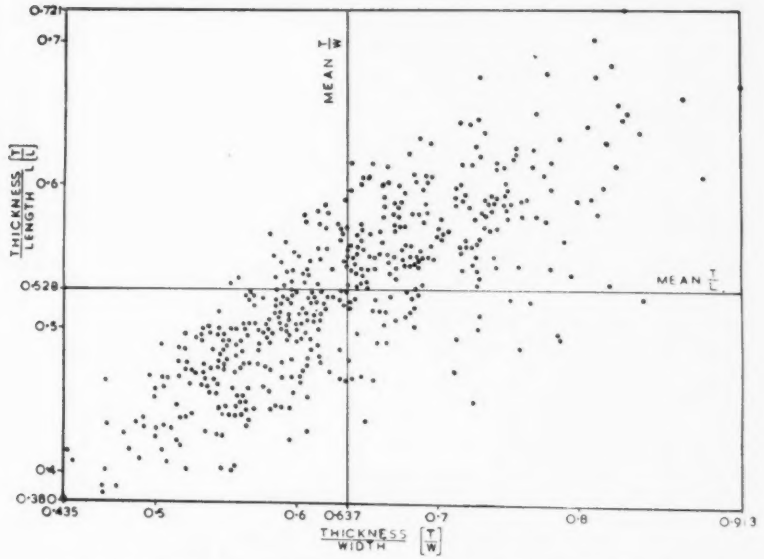
The regression equations (Text-figs. 5, 6, and 7) were obtained in the usual way by the method of least squares (the two groups of 457 and eighteen being considered separately) and the regression lines corresponding to these equations are drawn in the diagrams. The exponential forms of the regression equations are as follows :—

	Small size group, 457 specimens.	*Large size group, 18 specimens.*
y = length, x = width	$y = 1 \cdot 329x^{0 \cdot 960}$	$y = 0 \cdot 601x^{1 \cdot 258}$
y = thickness, x = width	$y = 0 \cdot 417x^{1 \cdot 165}$	$y = 0 \cdot 130x^{1 \cdot 595}$
y = thickness, x = length	$y = 0 \cdot 317x^{1 \cdot 187}$	$y = 0 \cdot 239x^{1 \cdot 196}$

The regression coefficients are compared below and it is concluded from Student's " t " test (see textbooks on statistical analysis) that in half the cases (i.e. those showing significance) the differences cannot reasonably be explained by random variation. It follows that the break in continuity of growth is probably a real one.

Length-width	Comparison of slopes	$t = 1 \cdot 993$	Significant at ·05 level
	Comparison of intercepts	$t = 2 \cdot 605$	Significant at ·01 level
Thickness-width	Comparison of slopes	$t = 1 \cdot 477$	Not significant
	Comparison of intercepts	$t = 1 \cdot 454$	Not significant
Thickness-length	Comparison of slopes	$t = \cdot 080$	Not significant
	Comparison of intercepts	$t = 3 \cdot 156$	Significant at ·01 level

The changes in the intercepts of the regression lines represent the sudden increase in growth rate of the length and the pause in growth of the thickness, the two lines being widest apart in the length-thickness diagram. The increases in slope of the length-width and thickness-width regression lines indicate that when normal growth was



TEXT-FIG. 9.—Diagram illustrating the fairly high degree of correlation between width and length at all thicknesses of specimens from the *Dielasma* bed.

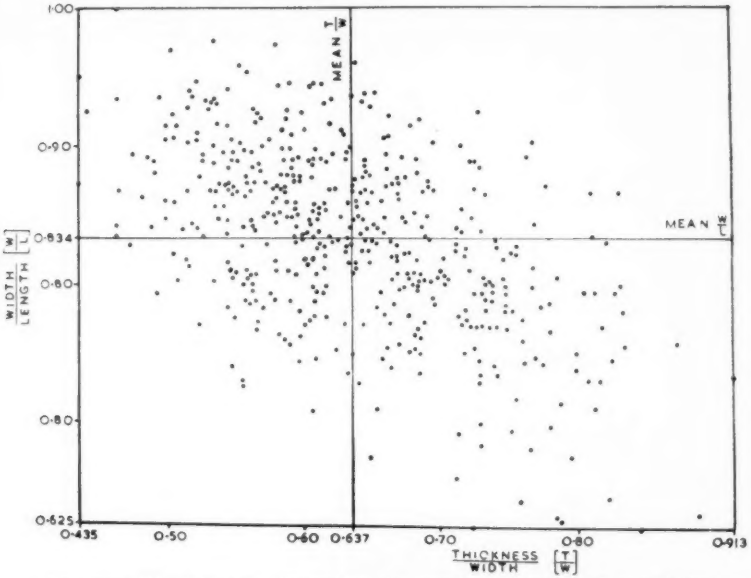
resumed the geometrical growth ratios had changed, and by a roughly similar amount. The latter point is also suggested by the parallelism of the length-thickness regression lines.

VARIATION

The frequency distributions of the different ratios (Text-figs. 2 and 3) indicate a usual range of variation for the *Dielasma* bed specimens, and the range is not increased greatly by the inclusion of the fifty-two additional specimens.

The extent to which the variability of individual dimensions is dependent upon that of other dimensions is illustrated in Text-figs. 9, 10, and 11. In these diagrams the ranges of the ratios are represented by the sides of the rectangles, the intersecting lines representing the mean ratios. In Text-fig. 9, most of the points in the scatter are in the

diagonally opposite quadrants and indicate a large measure of correlation between the ratios thickness/length and thickness/width. This means that whatever the thickness the total length varies largely with the width. The correlation is less between thickness and length (Text-fig. 10) but is still appreciable. Little if any correlation exists between



TEXT-FIG. 10.—Diagram illustrating the moderate degree of correlation between length and thickness at all widths of specimens from the *Dielasma* bed.

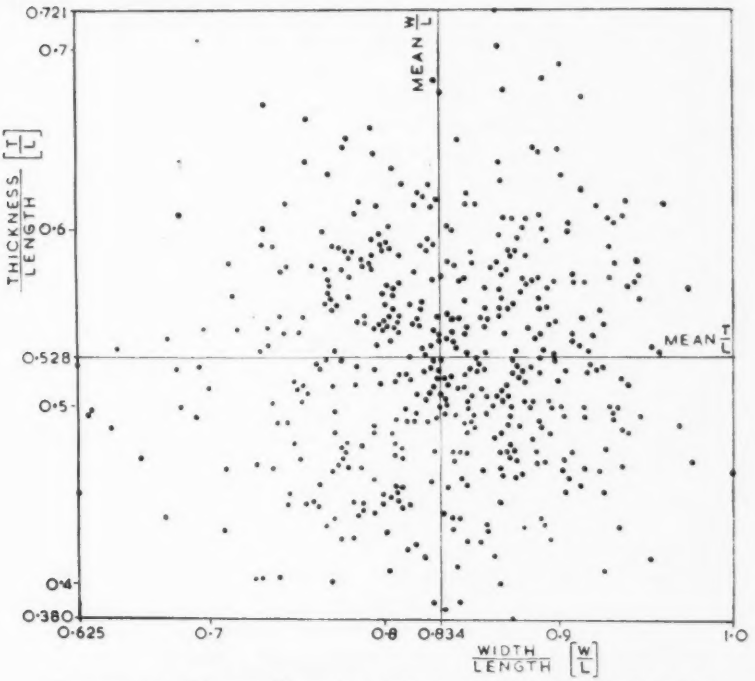
thickness and width (Text-fig. 11), and at all lengths the thickness and width vary independently. Since the width has been shown to be the best measure of age and the length is more closely correlated with it than the thickness, the length is the obvious choice as independent variable in the length-thickness regressions.

CONCLUSIONS

This investigation strongly suggests that all the specimens of *Dielasma* from Treak Cliff belong to the one species *hastata*. It indicates the probability that relative growth in this population is allometric in two stages, a break in the continuity of growth of the length and thickness occurring at a width of about 19 millimetres. Whether this is characteristic of the species generally or is confined to the one occurrence must await the examination of material from other localities.

The work further shows that the maximum width of the individual is the best measure of age, and it seems possible that this conclusion might be applicable to brachiopods generally, thus confirming a suggestion made by Burma (1948).

As is evident from a comparison of Text-figs. 5, 6, and 7 with



TEXT-FIG. 11.—Diagram illustrating the lack of correlation at all lengths between width and thickness of specimens from the *Dielasma* bed.

Text-fig. 8 the present investigation, so far as it goes, is consistent with the view that the use of the allometry equation can be valid in comparing the growth of two parts when the two parts separately have an allometric relation to the whole organism.

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Structural Imperfections in Alpine Quartz Crystals

(PLATE VII)

By C. FRIEDLAENDER

ABSTRACT

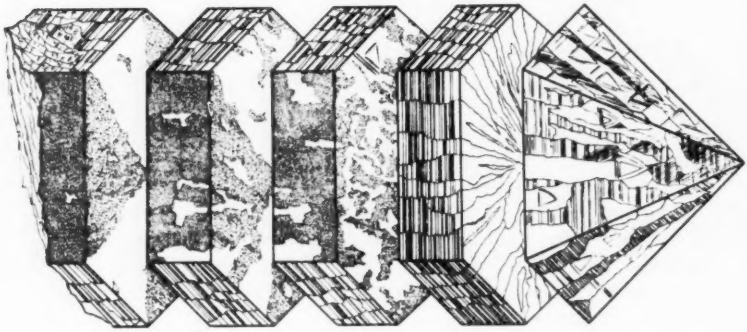
A description is given of structural imperfections such as twinning, lineage sutures and optical streaks, in Alpine quartz crystals.

AT the suggestion of Professor Niggli, the "usability" of Alpine quartz crystals for piezoelectric communication equipment was systematically investigated. It was ascertained that carefully selected parts of Alpine quartz crystals gave quite satisfactory results (Friedlaender, 1944, 1951; Friedlaender and Locher, 1945; Hedinger, 1948). The inadequate total quantity of available high-grade Alpine quartz crystals sets rather narrow limits to their use. Furthermore, a precision orientation may be rendered deceptive by characteristic structural imperfections. Whereas the technical importance of Alpine quartz is slight, at least in normal times, some of the observations made may be of general interest.

Twinning.—Dauphiné twinning was found to some extent in all Alpine quartz crystals examined. With respect to the extent of twinning and to the course of the twin boundaries within the crystal, different types can be distinguished ranging from almost complete absence of Dauphiné twinning to intricate twinning throughout the whole crystal. Generally speaking, the twin boundaries grow more intricate toward the apex of the crystal, that is to say with decreasing temperature, while the bottom of the crystals frequently show a far simpler pattern of intergrowth of the parts of a Dauphiné twin. There is obviously a fundamental difference between Dauphiné and Brazil twinning. R–L twins appear, in fact, not to be developed with the same facility as Dauphiné twins where both parts involved are of the same hand. From morphological evidence only, Brazil twinning is recognizable in Alpine quartz crystals in very rare instances. It is fairly frequent, however, in small peripheral regions of evidently late formation relative to the host crystal, as satellite crystals in the sense of Gaudefroy (1933).

Lineage Sutures.—According to a commonly held belief, Alpine quartz crystals could not be used at all for piezoelectric applications on account of their intricate twinning. This belief very likely was founded on an erroneous interpretation of the sutures: they are frequently taken as an indication of twinning. The sutures, seam-like lines running roughly parallel the c-axis, cut the horizontal striation on prism faces which is due to alternation of prism- and steep rhombohedral planes so as to cause a marked discontinuity. While there

are true twinning seams, it must be emphasized that these sutures are quite distinct from twinning. On the other hand, the sutures are an indication of lineage structure such as occurs frequently and in many minerals (see Buerger, 1934). A line drawing (Text-fig. 1) schematically shows the internal lineage and twin structure of an Alpine quartz crystal ; the sutures are seen to be independent of the twin boundaries.



TEXT-FIG. 1.—Schematic diagram of an Alpine quartz crystal of hexagonal habit. The crystal is dissected by four cuts normal to the c-axis into five parts. The rhombohedral faces show natural etching, sutures, and horizontal striation.

Z-slab 1 : on polished Z-plane, lamellar lineage boundaries (represented with some exaggeration). Sutures on prism faces intersected by horizontal striation.

Z-slab 2 : etched Z-plane shows intricate boundaries of Dauphiné twinning and small region with Brazil twinning. Prism facing front finely gound and etched so as to show course of twin boundaries.

Z-slab 3 : Z-plane and one prism face etched.

id. on Z-cut of basal portion of the crystal. Twin boundaries are seen to be far simpler in basal part of crystal than in upper part.

Throughout, lineage sutures independent of twinning.

Optical Streaks.—Viewed in parallel light, a slab of a certain thickness and with two polished parallel faces (as represented in the Z-slab 1 of Text-fig. 1) will reveal optical streaks, similar to those observed when dissolving sugar in water. These streaks (Plate VII, fig. 1), however, are not due to dissolution of any foreign material ; they are accounted for solely by a slight difference in orientation of adjoining lamellae. If the optical axes of adjoining lamellae in a quartz crystal differ from each other, there will be a certain difference in refraction, $n_\gamma - n_{\gamma 1}$. For a difference in orientation of 3°, $n_{\gamma 1}$ would be $1{\cdot}5534 \times \cos 3^\circ = 1{\cdot}5508$; $n_\gamma - n_{\gamma 1} = 0{\cdot}0026$. For a difference of 4° between adjoining lamellae, $n_{\gamma 1}$ would be 1·5492 and $n_\gamma - n_{\gamma 1}$

0·0042. Differences of refraction of that importance must be quite perceptible.

In a thick slab, there will be a considerable amount of superposition. This may explain the observation that the streaks seem to lie nearer to each other than would be inferred from observation in any plane normal to the viewing direction and that on tilting the slab slightly the streaks appear to move. In polarized light, polished Z-slabs reveal contrasting patches of strong interference colours. This is due to the optical activity and to the lineage structure.

Some observations of optical streaks in polished quartz slabs have been described by various authors (Kundt, 1883 ; Laemmlein, 1937 ; Töpler, 1864, 1866, 1867 ; Weil, 1931), but no explanation had been attempted. The observation of streaks in polished slabs presents a very sensitive means of detecting structural imperfections.

The lineage structure is clearly recognized when plates cut parallel to the c-axis, as X-cuts and Y-cuts, are viewed in polarized light. As a rule such a plate prepared from an Alpine crystal will not extinguish uniformly. One may observe differences in the orientation of the c-axis of adjoining lineages up to 3°. Laue diagrams within single lineages appear normal apart from showing a rotation of about 3° around the c-axis ; the superposition of lineages results in doubling of X-ray spots.

On observation with low power magnification, the borders and termination of the lineages become discernible as irregularly tilted, wedge-like seams of birefringence (Plate VII, fig. 2). A very conspicuous deviation of the lineages may be reminiscent of accessory heteroaxial twinning (Plate VII, fig. 3).

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EXPLANATION OF PLATE VII

FIGURE 1.—Optical streaks. Polished Z-slab, about 2 cm. thick, of R-quartz, Furka. Length of crystal 25·7 cm., diameter 8 cm. Viewed in parallel light, 1 : 1.

FIGURE 2.—Lineage structure. Borders and termination of lamellae. X-cut plate, 1 mm. thick, Z running N.–S. L-quartz, Göscheneralp. Seams of birefringence, reveal tilting and divergence in orientation of adjoining lamellae. Polarized light. 18 : 1.

FIGURE 3.—Lineage structure. Borders of lamellae. X-cut plate, 1 mm. thick, Z running N.–S., L-quartz, Göscheneralp. Seams of birefringence reveal divergence of orientation suggesting analogy to hetero-axial twin. Polarized light. 18 : 1.

ANNOUNCEMENT

EMPIRE MINING AND METALLURGICAL CONGRESS

The Fifth Empire Mining and Metallurgical Congress will be held in Australia during April and May, 1953, at the invitation of the Commonwealth of Australia and the Dominion of New Zealand. Full details are given in the First Circular, which can be obtained from :

The Secretary,
Fifth Empire Mining and Metallurgical Congress,
399 Little Collins Street,
Melbourne,
Victoria, Australia.

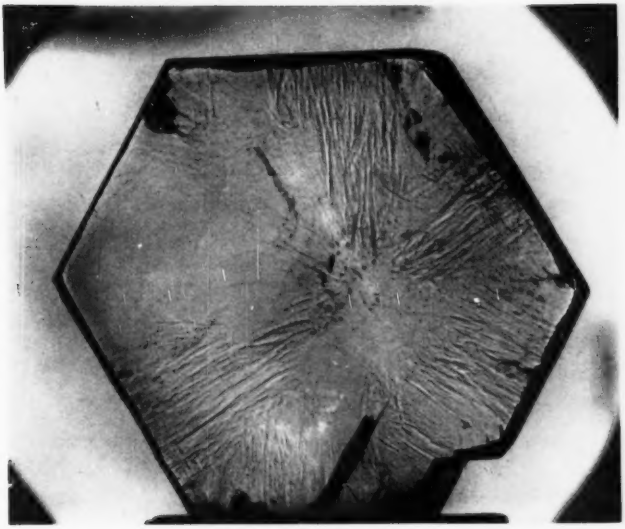


FIG. 1.

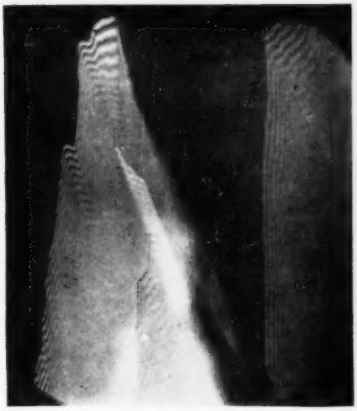


FIG. 2.

FIG. 3.

STRUCTURAL IMPERFECTIONS IN ALPINE QUARTZ.

Cyclic Resection of Headlands by Marine Erosion

By C. A. Cotton

(PLATE VIII)

Abstract

Though good examples of plunging cliffs surviving as such are now rare, this form of shoreline was probably commoner in the initial stages of the current (postglacial) cycle of marine erosion. Most cliffs now bordering the sea, whether developed from initially plunging cliffs or not, have already receded some distance from the initial shoreline.

As plunging cliffs may, because of reflection of waves from them, enjoy some immunity from direct frontal attack, the headlands which they truncate may be more vulnerable to marine erosion on the flanks, where the slopes partially submerged by shift of ocean level are less steep. Flank attack may lead to resection of the headland in such a way that eventually it will again end distally in a straight line of cliff; but at an intermediate stage of this resection cycle the terminations of headlands are characteristically scalloped, while at a penultimate stage of resection the salient of submaturity may be reduced to a row of stacks, the "needles" stage.

RECOGNITION of glacio-eustatic oscillation of sea-level makes it necessary to recast most generalized theories of shoreline development and of the development of coastal profiles. A simple deductive scheme of continuous erosional and depositional processes and of changes brought about by them while sea-level remains fixed is still useful as a standard concept, and such a theory is wholly satisfactory for the explanation of the features of some shores bordering soft terrains in places where the marine processes operate at fairly fast tempo. On many coasts, however, the coastal processes, in particular retrogradation, or cliff-recession, work much more slowly, and the details of the coast to-day may differ but little from those which were in existence prior to withdrawal of the sea from the near vicinity of present shores during the last world-wide glaciation. Thus, the history of these coasts must take into account modifications in greater or less degree attributable to former cycles conditioned by the changes in sea-level that have taken place from time to time.

Development of the near-shore and offshore submarine profile in relation to sea-level oscillation must have been a complex process in which episodes of degradation by marine erosion and abrasion at times of low sea-level have alternated with sedimentational infillings that have taken place when the sea has been high between glaciations; and investigation of this profile and its development awaits new methods of sea-floor research. As regards the outline of the shore, however, and erosional cliffing of marginal land, associated with progradation of parts of the shoreline, the significant features are in

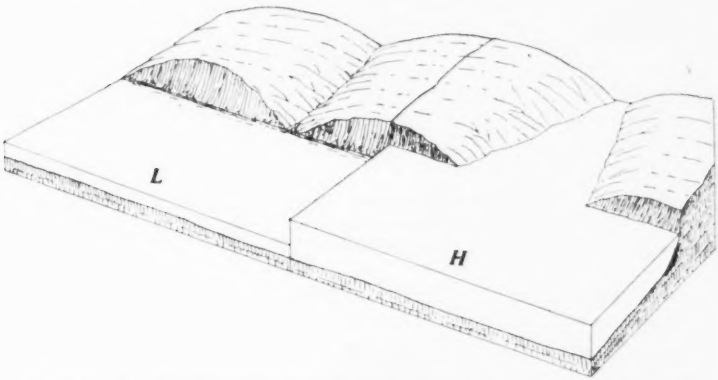
plain view, so that it is possible in some cases to separate shoreline and cliff forms attributable to successive cycles. These are, of course, only the cycles corresponding to the successive high stands of the oscillating sea-level, those taken in interglacial ages—some of them higher than the sea-level of to-day, though there must also have been others somewhat lower, the latter probably interstadial.

Assuming that the majority of cliffed coasts truncating hard rocks must have developed their outlines in such a succession of cycles, it is inherently probable that traces of cliff forms dating from the last of the interrupted high-sea-level cycles and possibly some from earlier ones are still to be found. The cliff profile may be two-storied (Cotton, 1950) or even multi-storied. As regards the outline, it might be worth while to deduce an erosional history continuing through successive cycles with various assumptions of initial form. One case of particular interest, which will be here examined, is that in which plunging cliffs have been produced in the postglacial positive movement of ocean-level. The best known examples of such coasts border basaltic volcanic-island domes which are submaturely or maturely dissected—for example, Tahiti (Davis, 1928), Banks Peninsula, on the east coast of the South Island of New Zealand (Davis, 1928 ; Cotton, 1944), and the sub-Antarctic islands far south of New Zealand, notably Campbell Island (Oliver, 1950), which resembles Banks Peninsula with the western half trimmed off by marine erosion activated by the gales of the Southern Ocean.

Characteristics of such island coasts which favour the development and preservation of plunging cliffs are : (1) the tendency of basalt lava flows to terminate in marginal escarpments with near-vertical profile when they are cut back by marine erosion ; (2) slow tempo of dissection of hard basaltic terrain ; and (3) absence, because of island isolation, of beach-making, spit-building, and prograding sands and gravels of extraneous origin, such as travel far along mainland coasts. Another contributing cause, notably at Banks Peninsula, is isostatic sinking of the heavy basaltic mass which, if still slowly continuing, will counteract the effects of long-term eustatic lowering of ocean level so that the shorelines of anterior cycles are submerged.

A monopoly of plunging cliffs cannot be claimed for basaltic islands, however ; they must be present at least in initial and infantile stages of postglacial marine transgression wherever coasts have been cliffed back so far in the preceding (glacial age) episode of low sea-level that the cliffs of the glacial age have destroyed the coastal plain then emergent and have undercut the former shore. In places where the continental shelf is very wide this is obviously a highly improbable case, but in regions with steep-to coasts bordering mountainous land such retrogradation can easily be pictured as taking place during

a protracted period of glaciation. Commonly, however, such plunging cliffs will fail to outlast the earliest stages of marine attack in a new cycle. Debris travelling alongshore, be it sand or shingle, together with that resulting from crumbling and subaerial erosion of the cliffs themselves, for these may intersect any terrain and are not generally endowed with basaltic immunity, will in the majority of cases soon fill in the re-entering angle at the now submerged cliff-base. Waves breaking on a ramp so formed, which is steep though not steep



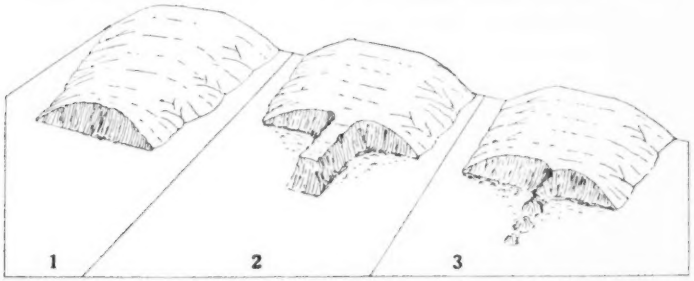
TEXT-FIG. 1.—Development of plunging cliffs on the margin of a dissected basalt dome. *L*: Late Pleistocene low sea-level stage; and *H*: post-Pleistocene high sea-level stage. As in the case of Banks Peninsula, valleys are now drowned to form bays between headlands truncated by plunging cliffs.

enough to reflect them, will attack the shore with maximum vigour, so that cliff retreat will go on amain and before long all traces of a former plunging-cliff condition will be obliterated.

Such a metamorphosis has not been the fate of stable, non-crumbling, near-vertical cliffs of basalt in island isolation. Cliffs of Banks Peninsula drowned by postglacial return of the ocean still plunge into deep water (20 fathoms deep along the southern side, Plate VIII, which is swept by a northward ocean current, preventing sedimentation); and reflection of ocean swell from these is often clearly seen (Plate VIII), as out-running, reflected waves curl over and break into foam. Waves thus reflected from a wall do it little damage, and such waves as do actually break against plunging cliffs are impotent to erode, being unarmed with debris owing to absence of beach or scree material in the breaker zone, though a talus of fallen blocks may be present at greater depth. Thus, the immunity of these cliffs

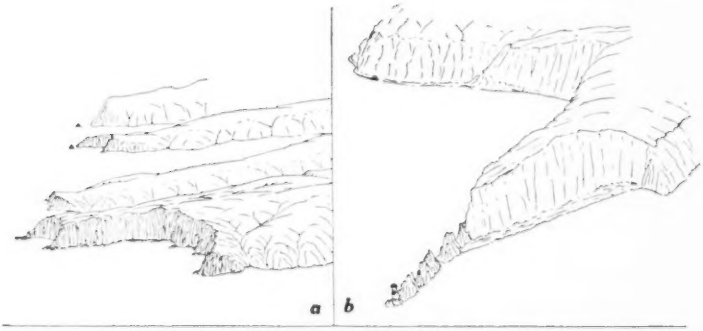
from retrogradation by direct wave attack is almost perfect. (Such cliffs are shown in Text-fig. 1.)

It is of some interest to find, nevertheless, that headlands terminated distally by such almost everlasting plunging cliffs are subject to flank attack, as shown in Text-fig. 2. While typical basalt cliffs at the ends



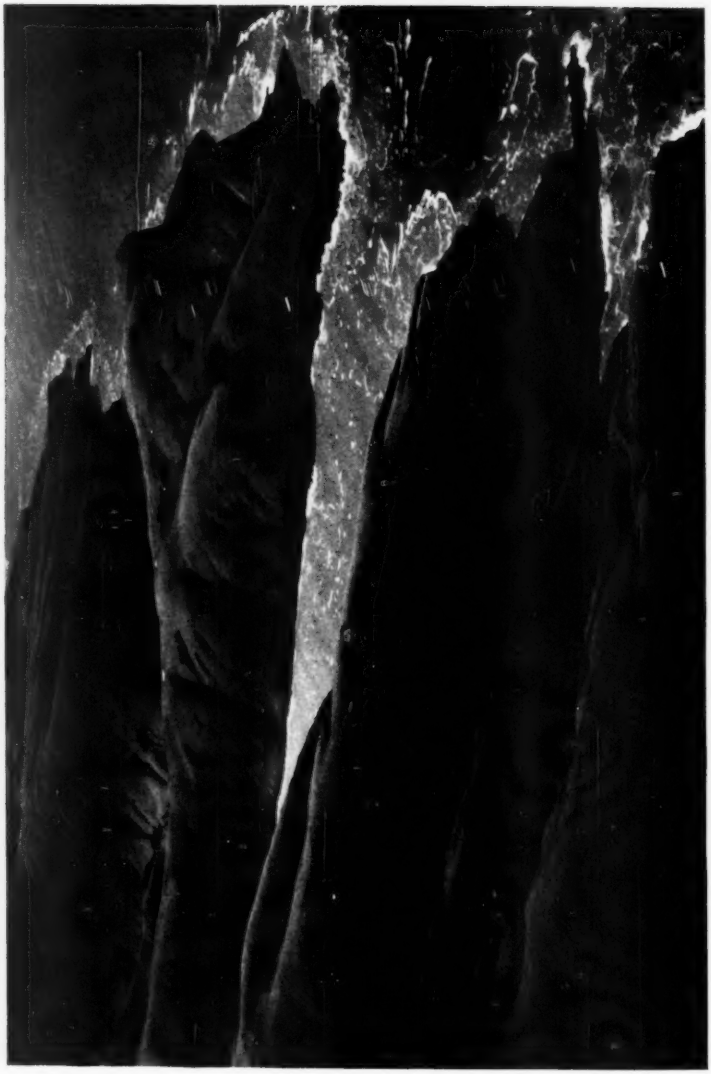
TEXT-FIG. 2.—Cliff forms of successive stages of a cycle of resection of headlands. (1) Initial stage (plunging cliffs); (2) intermediate or submature stage; (3) penultimate or "needles" stage.

of headlands are nearly vertical, and plunge, so as to inhibit erosion, the profiles on their flanks, bordering the bays produced by drowning of valleys, are considerably less steep. Erosion may start on these,



TEXT-FIG. 3.—(*a*) Headlands resected to submaturity, south side of Banks Peninsula.
(*b*) The Needles and western cliffs of the Isle of Wight. Sketched from a reproduction of a natural-scale model, by T. Bayley, in Stamp (1951).

and once started grows by what it feeds on, becoming more and more vigorous, so that new cliffs are formed and cut back. This may take place on both flanks at an equal rate; but generally the attack will be particularly effective on whichever side faces the more frequent



PLUNGING CLIFFS OF BANKS PENINSULA.

strong winds and heavier seas, and the result is an asymmetric truncation. Whether the attack is vigorous on both sides (Text-fig. 2) or on one only (as illustrated by headlands of Banks Peninsula, where headlands projecting both north and south are attacked by waves from an easterly direction), the distal portion of the headland is reduced in the course of time to a narrow cliff-walled strip (Text-fig. 2, stage 2, and Text-fig. 3, *a*). Later it must dwindle to a row of stacks (Text-fig. 2, stage 3), and when these are destroyed the cycle is completed with resection of the headland and restoration of the terminal straight cliff line (not at this stage plunging, however).

The western end of the Isle of Wight has apparently been subjected to a similar flank attack on its terminal cliff. It would seem that the cliff behind the Needles (Text-fig. 3, *b*), themselves relics of the distal part of a residual strip thus isolated, had been attacked by erosion from each side in some marine cycle, though perhaps not the last. This suggests that owing to some local combination of circumstances the cliff has been of the plunging kind in the episode in which the flank attack began.

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EXPLANATION OF PLATE VIII

Banks Peninsula, New Zealand. View eastward from a point above Akaroa Heads, showing plunging basalt cliffs from which the ocean swell is reflected. (Photograph by V. C. Browne.)

CORRESPONDENCE

FORAMINIFERAL ZONES IN THE TERTIARY OF AUSTRALIA

SIR,—Dr. M. F. Glaessner recently published a paper in this Journal (lxxxviii, 1951, 273–284) in which he describes foraminiferal zones in the Tertiary of Australia and in which he summarizes known and unpublished information on the Australian Tertiary sequence. A great deal of precise stratigraphic work has been done on the Australian Tertiary rocks in the past five years. Dr. Glaessner cannot have been unaware of this and it is regretted that he did not wait until the results of it were available. Recent discoveries since Glaessner's paper was prepared have made necessary a drastic revision

of the age correlations of the Victorian Stages and have emphasized the undesirability of prematurely publishing material based on investigations which are still in progress.

He lists what he calls "three distinctive foraminiferal zones", (1) *Hantkenina alabamensis* Zone, (2) *Victoriella plecte* Zone, and (3) *Austrotrillina howchini* Zone. In his correlation table on p. 274, he indicates a fourth, "? *Sherbornina* Zone," which may be of zonal value. Recent investigations by Raggatt and Crespin (1952) in the Bird Rock section, Torquay, Victoria, which has been regarded as the type area for the "Janjukian Stage", and westward as far as Brown's Creek and Johanna River, have shown that the proposal of *Hantkenina*, *Victoriella*, and *Sherbornina* as distinct zones is incorrect. In the basal portion of the Bird Rock Cliff section, these three forms occur together in the one sample, whilst *Victoriella plecte* has been found in the Upper Eocene beds at Johanna River and Brown's Creek. *Sherbornina atkinsoni* is common in many rock samples containing *Victoriella* in the vicinity of Bird Rock and Point Addis and its occurrence in beds higher in the stratigraphic sequence is extremely rare. "The possibility of establishing a zone based on the occurrence of *Sherbornina* between *Victoriella* and *Austrotrillina* Zones" (p. 278) seems quite untenable. The presence of *Hantkenina alabamensis* in the basal beds at Bird Rock definitely gives an Upper Eocene age for at least the lower part of the so-called "Janjukian Stage", which Glaessner has put down as Upper Oligocene.

According to Glaessner (p. 281) "*Victoriella* does not give any direct age indications". The writer believes that, in the absence of *Hantkenina alabamensis*, *Victoriella plecte* will prove an important age determinant for the Upper Eocene because of its ability to thrive under calcareous or argillaceous conditions. Also, on account of its comparative abundance, it is found in many places where the search for *Hantkenina* is unsuccessful.

On p. 277 Glaessner states that "the *Hantkenina* Zone of Brown's Creek is developed as a glauconitic clay with *Notostrea* forming the lowest fossiliferous bed of a sequence of Tertiary strata which rests, with unfossiliferous ironstones at its base, unconformably upon Jurassic sandstones". Raggatt and Crespin (1952) found that 35 feet of clays containing abundant foraminifera and mollusca are exposed in a continuous section below the bed with *Hantkenina* and *Notostrea*, and that Jurassic rocks are not exposed at this place. Field measurements show that beneath these very fossiliferous beds there is a thickness of 166 feet of Tertiary strata. Also beds with *Hantkenina* are not at the top of the Eocene in Brown's Creek–Johanna River section as shown in the correlation table on p. 274; there are at least 145 feet of beds containing Upper Eocene foraminifera above them. The species recognized include *Anomalina perthensis* Parr, *Angulogerina subangularis* Parr, *Alabamina obtusa* (B. & H.) var. *westraliensis* (Parr), *Bolivinopsis crespinae*, *Asterigerina adelaidensis* (Howchin), *Cibicides pseudoconvexus* Parr, and *Pseudobulimina glaessneri* Howe and Roberts.

On p. 278 Glaessner refers to "carbonaceous, pyritic sands and sandy clays with *Cyclammina*" as occurring above the *Hantkenina* zone. Instead, the *Cyclammina* beds of the "Anglesean Stage" stratigraphically underlie the beds containing *Victoriella* and *Sherbornina* in the Point Addis section. This sequence is common in many of the bores in Gippsland, in the Mallee and in south-western Victoria and the age of the *Cyclammina* beds is very probably Middle Eocene. The writer has examined a considerable amount of material from the section at Anglesea (Singleton, 1941). *Cyclammina* is exceedingly abundant there and many tests are beautifully preserved. Species are readily determinable rather than "not being identifiable owing to distortion" as stated by Glaessner.

Many of Glaessner's comments regarding *Austrotrillina howchini* (pp. 276, 279, 281) are taken from published and unpublished work of the writer, who adheres to her views on the distribution in Australia of this important Miocene Indo-Pacific species (Crespin, 1948, 1950). Similarly, the stratigraphic position of *Flosculinella bontangensis* has been determined by the study of

measured sections in North-West Australia. More recent research, however, shows that both of these forms must be considered as zonal species, in North-West Australia, for " f1 " stage of the Indo-Pacific " letter classification " (Van der Vlerk, 1948) rather than of " f2 ". The upper limit of *A. howchini* has not been definitely proved in South-Eastern Australia. It is also admitted that " f1 " stage is most probably Lower Miocene.

It is difficult to understand why Glaessner in the correlation table on p. 274, should correlate his foraminiferal zones in Australia with definite European Stages of the Tertiary, for example, the *Sherbornina* Zone with the Aquitanian and the *Victoriella plecte* Zone with the Chattian. Surely a long distance correlation of zones in the Australian Tertiaries with European Stages would require the presence of similar zonal species in the foraminiferal assemblages in both parts of the world. It was the absence of similar species in the deposits of these two widely separated regions that caused the early Dutch paleontologists to institute the " letter classification " for the East Indian Tertiaries. In spite of the very considerable detailed work that has been done there, agreement has still not been reached about the correlation of European Stages with Indo-Pacific Stages of Zones.

The correlation of Eocene and Lower Oligocene deposits throughout the world by means of the foraminifera and especially the larger foraminifera is relatively easy. Forms such as *Discocyclina*, *Assilina*, and *Pellatispira* are unknown in rocks younger than Eocene. Amongst the smaller zonal genera, *Hantkenina* is characteristically Middle to Upper Eocene and some of the smaller foraminiferal Eocene species are also widely distributed. It has been generally recognized that the association of reticulate *Nummulites* with *Eulepidina* represents stage " d " in the East Indies which by some authors is correlated with the Rupelian or Middle Oligocene. Beds of Oligocene age are poorly developed in the Indo-Pacific region and in some places are absent.

Tan (1939) regarded the Aquitanian as Lower Miocene or Lower Neogene and suggested that certain beds in the Indo-Pacific region which contained European species of *Eulepidina* such as *E. dilatata*, *E. elephantina*, and *E marginata* could be correlated with the Aquitanian. He urged " that at the present state of knowledge the differentiation of Oligocene from Aquitanian by means of larger foraminifera is only possible if reticulate or other genuine Camerines are present ". Recent research seems to indicate that the Aquitanian is Oligocene-Miocene.

Tan (1939) said it was very difficult to differentiate the Burdigalian Stage and higher European Stages in the Indo-Pacific because of " fundamentally different " marine faunas in Southern Europe and in the Indo-Pacific. It is a well recognized fact that distinct faunal provinces existed throughout the world during Miocene times. Genera such as *Katacycloclypeus*, *Tryblio-lepidina*, and *Alveolinella* and several species of *Miogypsina* and *Nephrolepidina* which are widely distributed in Miocene deposits in the Indo-Pacific region are unknown in the European beds. Furthermore, *Miogypsina* and *Lepido-cyclina* disappear in the Burdigalian in Europe whereas they continue to live during later Miocene times in the Indo-Pacific region. Rayed forms of *Lepidocyclina* with nephrolepidine-trybliolepidine and trybliolepidine embryonic apparatus dominate the " f " stage (Miocene) assemblages in the Indo-Pacific region and are unknown in European assemblages.

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CANBERRA.

3rd March, 1952.

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SIR,—(1) For the clearly stated purpose of the paper criticized by Miss Crespin, observations made by the late Mr. Parr were combined with data published by Miss Crespin during the last decade. These were supplemented by a report on foraminifera from bores in the Adelaide Basin which was made available to the writer by the Mines Department of South Australia while it was in the hands of the printer as an Appendix to *Bulletin* No. 27 of the Geological Survey. This is the only "unpublished information" by Miss Crespin used in the paper where it is acknowledged as such. The salient points of her observations, i.e. the occurrence of *Austrotrillina* and *Sherbornina* in bores in South Australia, were published previously by Miss Crespin (1946, p. 300; 1948, pp. 138, 139, and Table I).

(2) I was well aware of stratigraphic work being done in the Australian Tertiary by Miss Crespin and others. I welcomed and acknowledged at the time the opportunity given by some other colleagues and organizations to visit and discuss with them critical areas in 1946. A similar field conference with Miss Crespin and her co-author was suggested by the writer in 1950 but this was not accepted. The results of their work are still unpublished at the time of writing, the bibliographic reference to Raggatt and Crespin, 1952, notwithstanding.

(3) Miss Crespin (1950, pp. 70–1) stated: "A detailed stratigraphic and micropaleontologic investigation of the cliff section along the southern coastline of Victoria . . . has been completed by H. G. Raggatt and the writer and the results will be published shortly. The study of the microfaunas in the sediments has yielded considerable information about the stratigraphic range of the foraminiferal species and it has been possible to determine the restricted vertical range of certain species. . . . The Anglesean Stage is considered to be Oligocene and the Janjukian, Lower Miocene." In the light of this statement and of what follows, Miss Crespin's remark about "the undesirability of prematurely publishing material based on investigations which are still in progress" may seem rather harsh self-criticism. Investigation of Tertiary strata hundreds to thousands of feet thick and extending over 700 miles of coastline and 150 miles or more inland will continue for many years during which, it is hoped, a vigorous policy of publishing and discussing observations and making tentative compilations will be maintained.

(4) It seems now that after the publication of her 1950 paper and of my contribution Miss Crespin has found *Hantkenina* in one sample of typical

Janjukian with *Victoriella*. If confirmed, this is a new fact not foreseen by anyone. From this Miss Crespin draws the conclusion that all beds with *Victoriella*, previously placed by her in the Middle and then in the Lower Miocene and by the writer in the Upper Oligocene, represent the *Hantkenina* zone and must be Upper Eocene. One would have expected an attempt to solve the problems created by this new correlation but they are not even stated. For example, the sequence is continuous from Janjukian to Balcombian (Batesfordian) at least in Western Victoria (Parr in Baker, 1944) and Gippsland. If the lower beds of the Janjukian are Upper Eocene and the beds conformably overlying this " stage " are Lower Miocene then the upper Janjukian must represent the Oligocene. In the Table Cape beds, at Spring Creek and Waurn Ponds (Janjukian) the squalodontid *Prosqualodon davidi* Flynn occurs which cannot be older than Late Oligocene (Romer, 1945, p. 490).

(5) As the beds with *Sherbornina* apparently follow conformably below the undisputed Batesfordian (Balcombian) equivalents in Gippsland and in the Adelaide area, they cannot be considered as " *Hantkenina* zone ", i.e. Eocene. Notwithstanding the longer range of the genus *Sherbornina* in the Torquay area and possibly Tasmania, of which I was well aware, its locally restricted range still offers the possibility of establishing a zone based on its stratigraphically restricted occurrence in these areas.

(6) It is noted with satisfaction that Miss Crespin has not changed her views on the distribution of *Austrotrillina* with the exception of the one point which I have criticized. It is now admitted to be " most probably " Lower Miocene.

(7) It is not difficult to understand why European Stage terms are placed against Australian zones when it is realized that these stages are " time-rock " divisions of the international standard stratigraphic scale and serve to place these zones in the world-wide continuum of geological time. The question of time stratigraphy and the " letter classification " will be more fully discussed elsewhere, as announced in my paper.

(8) The stratigraphic value of larger foraminifera is well known to me and to other students of the principles of micropalaeontology. The relation of Tan's opinions on this matter to the present discussion is, however, remote.

(9) In conclusion, I am gratified to see, firstly, new evidence coming to light and being promptly published ; secondly, agreement on the wide stratigraphic range and high antiquity of the south-east Australian Tertiary sequence which was denied by Miss Crespin as recently as 1945 and (Aldinga Bay) 1946 ; thirdly, agreement on the Lower Miocene age of the " Batesfordian " and apparently the stratigraphic relations of the younger strata. I am sure that the question of the extent of Eocene and Oligocene in Australia will be solved by further friendly co-operation and competition of many workers in the field.

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UNIVERSITY OF ADELAIDE.

17th April, 1952.

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GOLD COAST UNIVERSITY COLLEGE

SIR,—May I, through your columns, appeal for help for the University College of the Gold Coast ?

The Geology Department of this College is experiencing considerable difficulty in building up a teaching collection of fossils. There are few fossiliferous deposits in the Gold Coast itself and our collections must be built up from other countries. I am sure every long-established teaching department has a few spare fossils which it would be willing to part with for this purpose. Departments at home cannot, of course, fully realize the difficulties of starting from scratch. In the case of rocks and minerals fairly adequate collections can be bought, but it is more difficult in the case of fossils. It would, therefore, be a very great help, indeed, if other departments or individual geologists could send us some of their spare material, or if they could see their way to collect some for us during class excursions. This department would defray the costs of postage, or freight, and it would be best to send very small parcels by air. Packages by sea seldom reach us in less than six months and often take longer, so that it would be of the greatest help if anything available could be offered soon in order to reach us by the beginning of the new session in October. Packages addressed to The Bursar (for Geology) usually escape Customs· formalities.

WILLIAM J. MCCALLIEN.

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SPECIES AND SUBSPECIES

SIR,—Mr. McKerrow (*Geol. Mag.*, lxxxix, 148–150) and I (*Geol. Mag.*, lxxxviii, 88–102) disagree not in our appreciation of the phenomena but in their nomenclatural treatment. Mr. McKerrow prefers to call a morphological " species " what I regard as a morphological " variety ". I feel unhappy if I am asked to call by different specific names individuals from a single horizon which may be regarded as part of a single interbreeding " plexus " ; but Mr. McKerrow is as entitled to his opinion as I to mine, and certainly many palaeontologists would side with him and against me.

Mr. McKerrow has, however, misunderstood my intention in proposing quantitative limits to the range of a chronological subspecies. The fault is, I am afraid, mine, for others have misunderstood me in the same way. I intended to suggest that a chronological subspecies was an arbitrary length of lineage. If two populations, being members of such a lineage, are drawn from different horizons, and, on statistical analysis, their means are found to differ by more than 4σ in any character, they may be regarded as specifically distinct. If the difference is less than 4σ, they may be regarded as subspecifically distinct, but only if such distinction is both statistically significant *and of stratigraphical value*. It seems to me pointless to give distinct names to populations which, though statistically different, have no stratigraphical significance. Many very small topodemes of living animals, when statistically examined, are found to differ significantly (e.g. *Peromyscus* in North America ; *Cepaea* in this country). Nobody would suggest evaluating such " family " groups as geographical subspecies.

Mr. McKerrow accuses me of giving an incorrect definition of a geographical subspecies ; I did not give any definition at all.

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SHEFFIELD 1.

28th April, 1952.

ACCURACY IN GEOLOGICAL LOCALITIES: FURTHER COMMENTS

SIRS,—In his letter on the above topic published in your March/April issue (p. 152) Dr. Morley Davies writes of " two striking examples of inaccurate locality " one of which refers to the Geological Survey and Museum.

Concerning the first, we know of no instance of " Diss, Norfolk " appearing in the literature as a locality for Red Crag echinoids. In the " Catalogue of the Tertiary and Post-Tertiary Fossils in the Museum of Practical Geology " (1878), p. 49, *Echinus woodwardi* Desor is recorded from Coralline Crag at Diss. The specimen in question was presented to the Museum in 1851 by Capt. (later Lieut.-Col.) Henry Alexander, who resided at Diss at about this time (see *Quart. J. Geol. Soc.*, x, 1854, p. 334); and is referred to by Forbes, " Monograph of the Echinodermata of the British Tertiaries " (*Palaeont. Soc.*), 1852, p. 4, as *E. lamarckii* Forbes. J. W. Gregory (*Proc. Geol. Assoc.*, xii, 1891, p. 33), who regarded *E. lamarckii* as a synonym of *E. woodwardi*, also records the latter from Coralline Crag at Diss, though without explicit reference to any specimen. A. Bell (*Annual Rep. Yorks. Phil. Soc.* for 1920, 1921, p. 16) records *E. woodwardi* from " Mid.-glac. Diss . . . probably derived ". Alexander's specimen may, however, have come from Sudbourne (see *Proc. Geol. Soc.*, iii, 1838, no. 59, p. 10), a well-known Coralline Crag locality, but while it is true that neither Coralline Crag nor Red Crag occurs *in situ* at Diss, who, at this distance of time, can aver that Alexander's specimen was not collected from the local Boulder Clay; or that it was not acquired by him from a collector who told him that it came from Diss?

Concerning the *Rhaxella* chert, we are indebted to Dr. Davies for two specimens registered in our collections in 1913 and 1931 respectively. Despite the error of acknowledgment of the second presentation we can assure Dr. Davies that he was not the agent of any serious mistake in documentation since the locality of each was correctly entered in our registers.

C. J. STUBBLEFIELD.

GEOLOGICAL SURVEY AND MUSEUM,
LONDON, S.W. 7.
6th May, 1952.

Dr. Davies regrets that he wrote "Red Crag" instead of "Coralline", through trusting to memory when unable to check his references.—*Ed.*

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Geology and Physiography of the Kingston District, Jamaica. By C. A. Matley (edited by Frank Raw). Published on behalf of the Institute of Jamaica by the Crown Agents of the Colonies, London, 1951. pp. vii + 139, with 14 figures and 20 plates (including 2 folding maps, one in colour). Price 21*s*.

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